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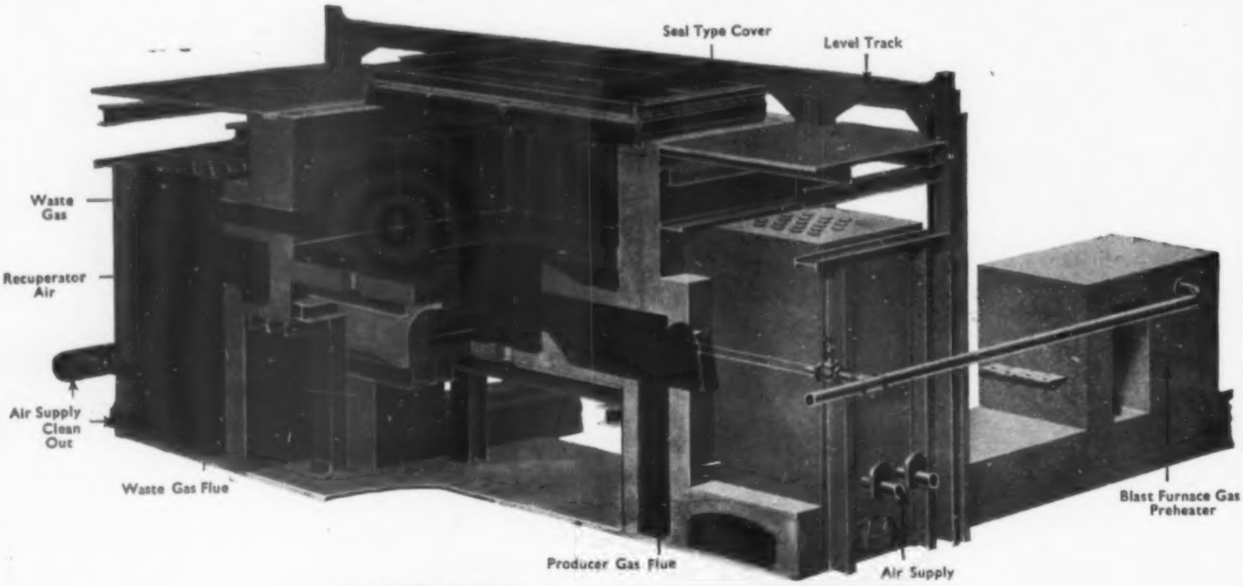

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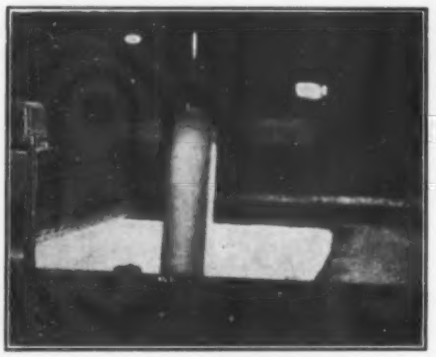

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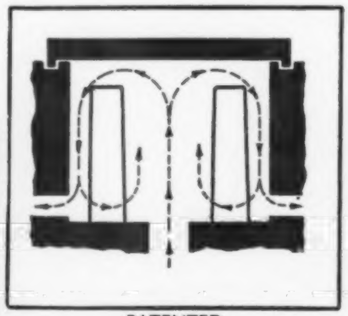

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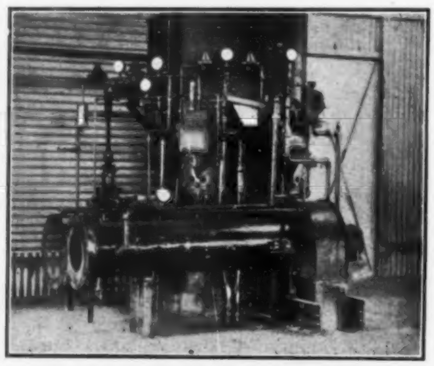

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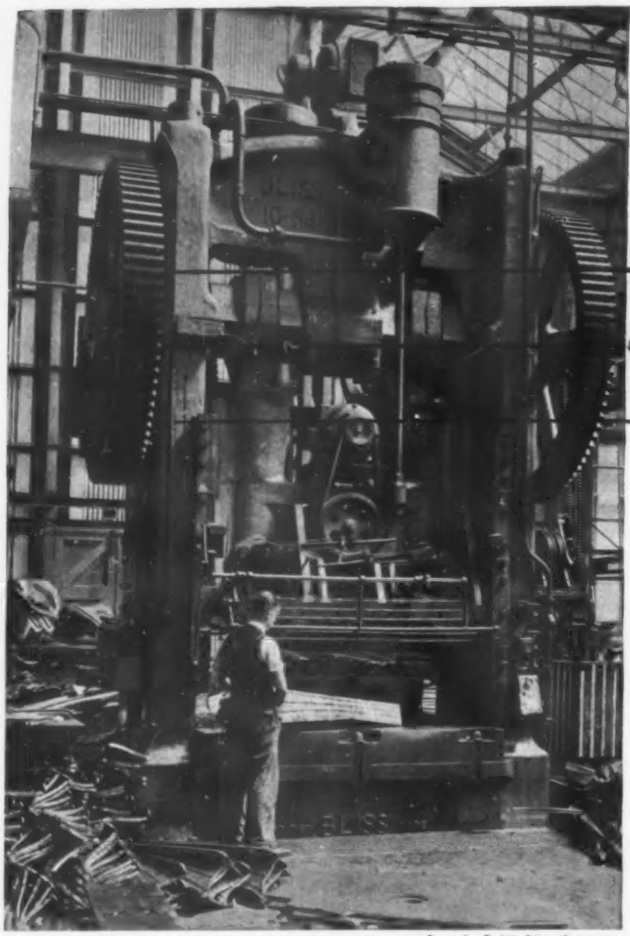

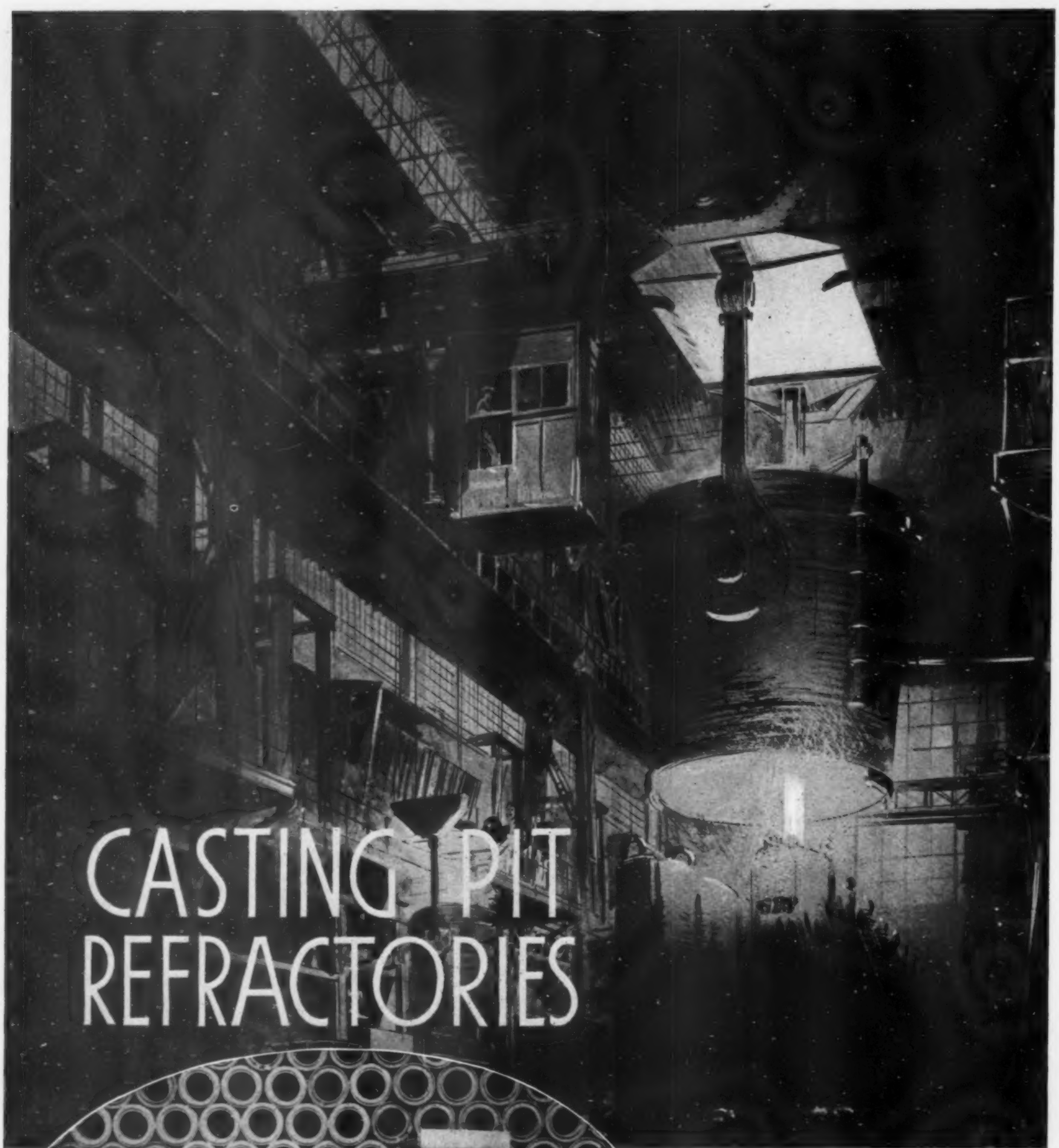
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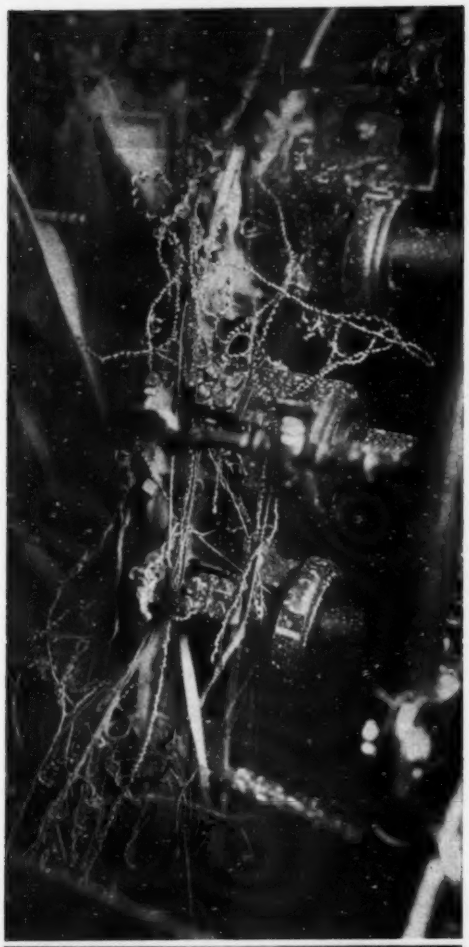

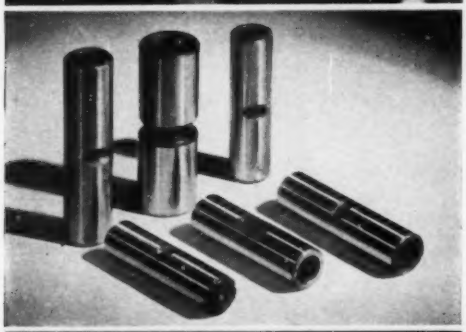


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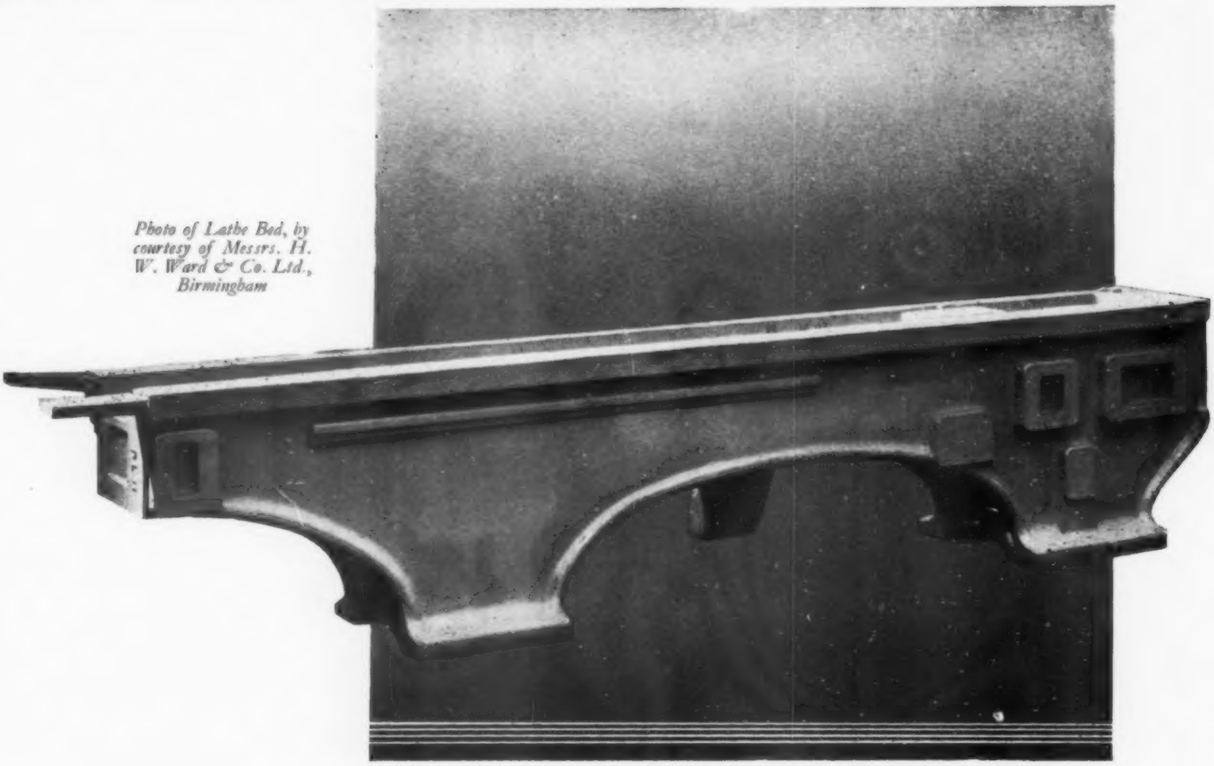

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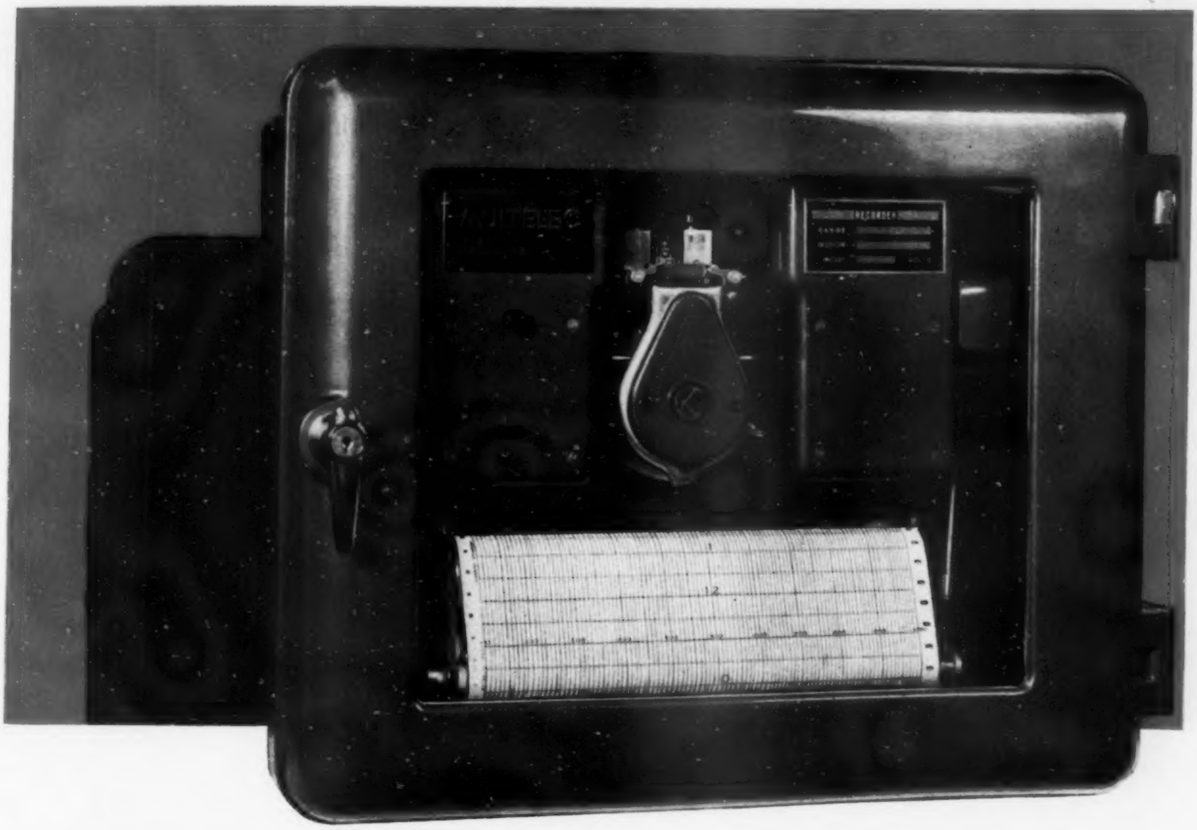

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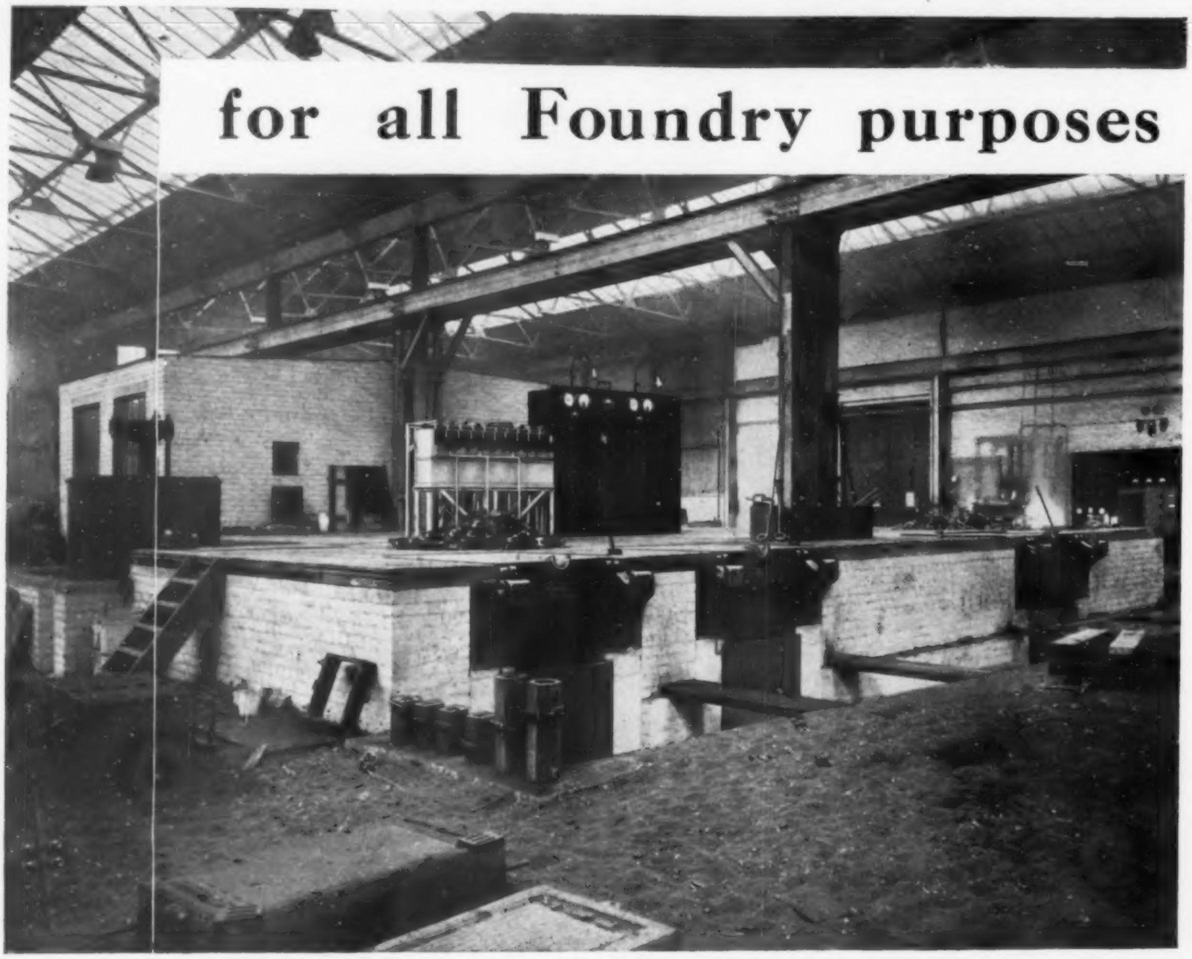

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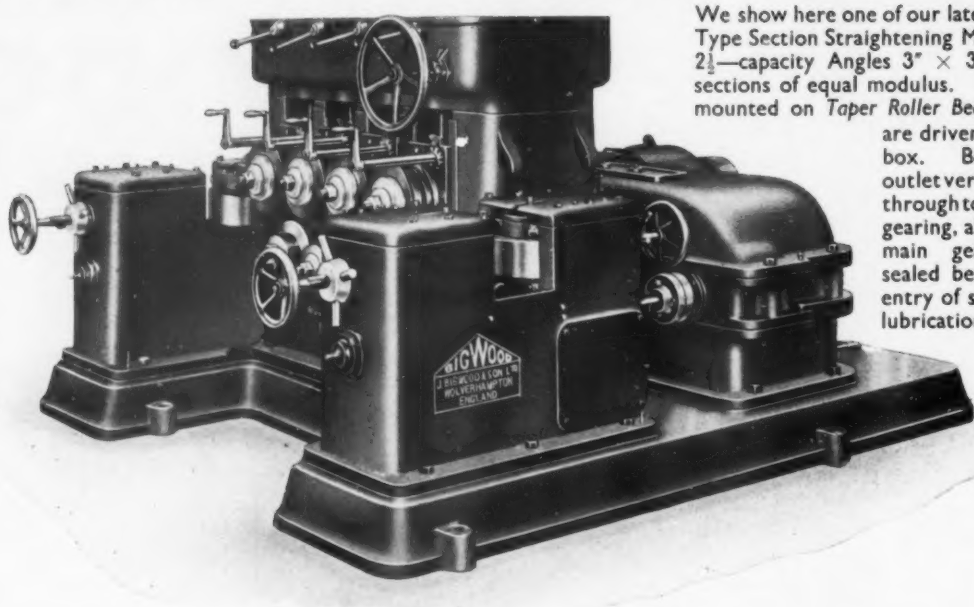

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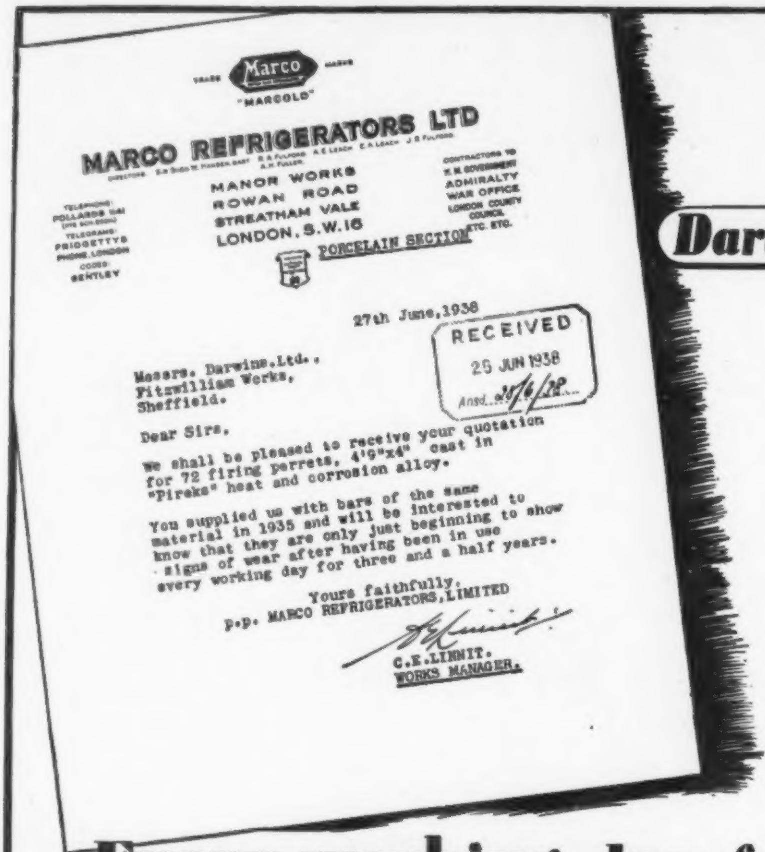

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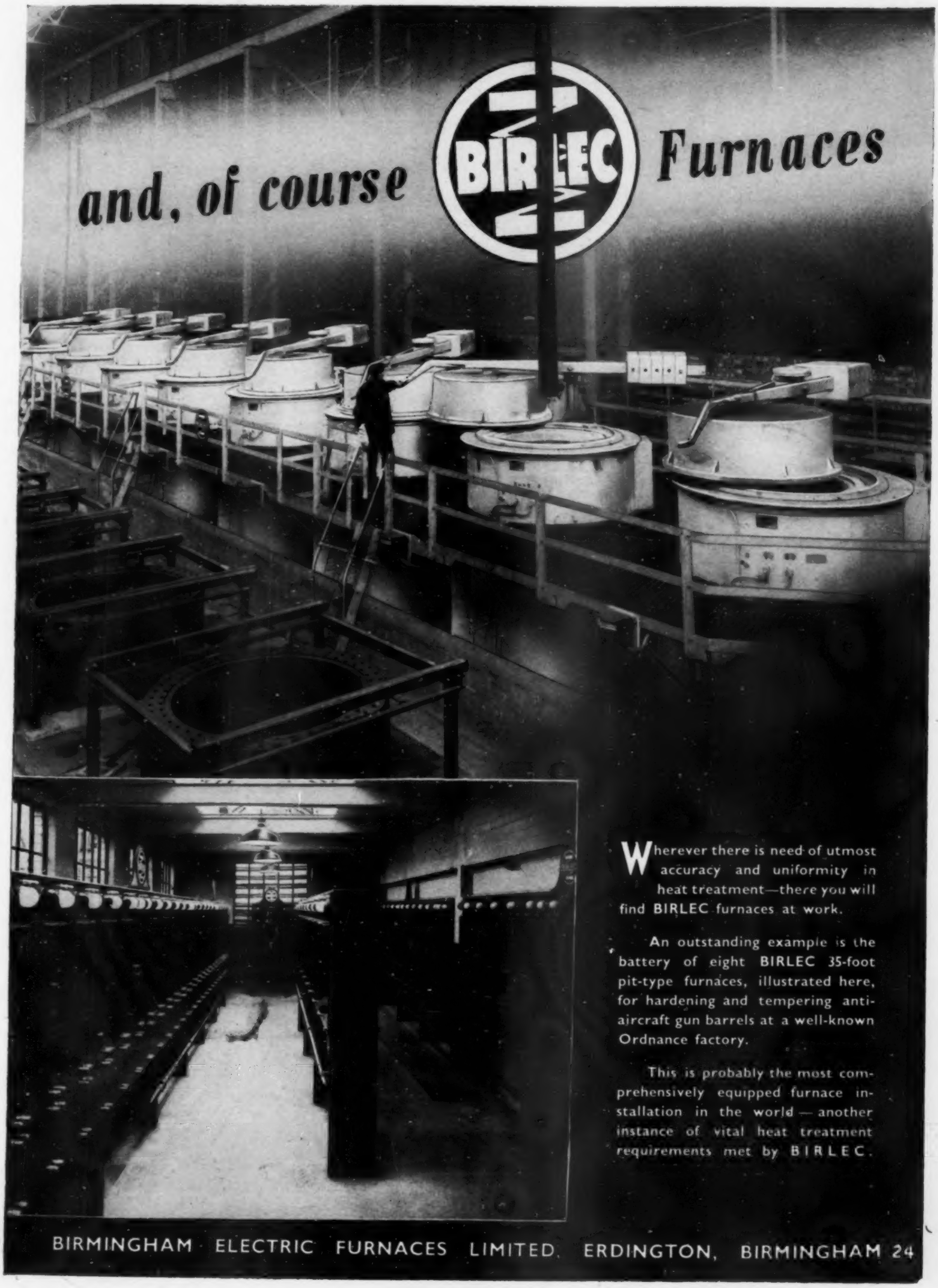
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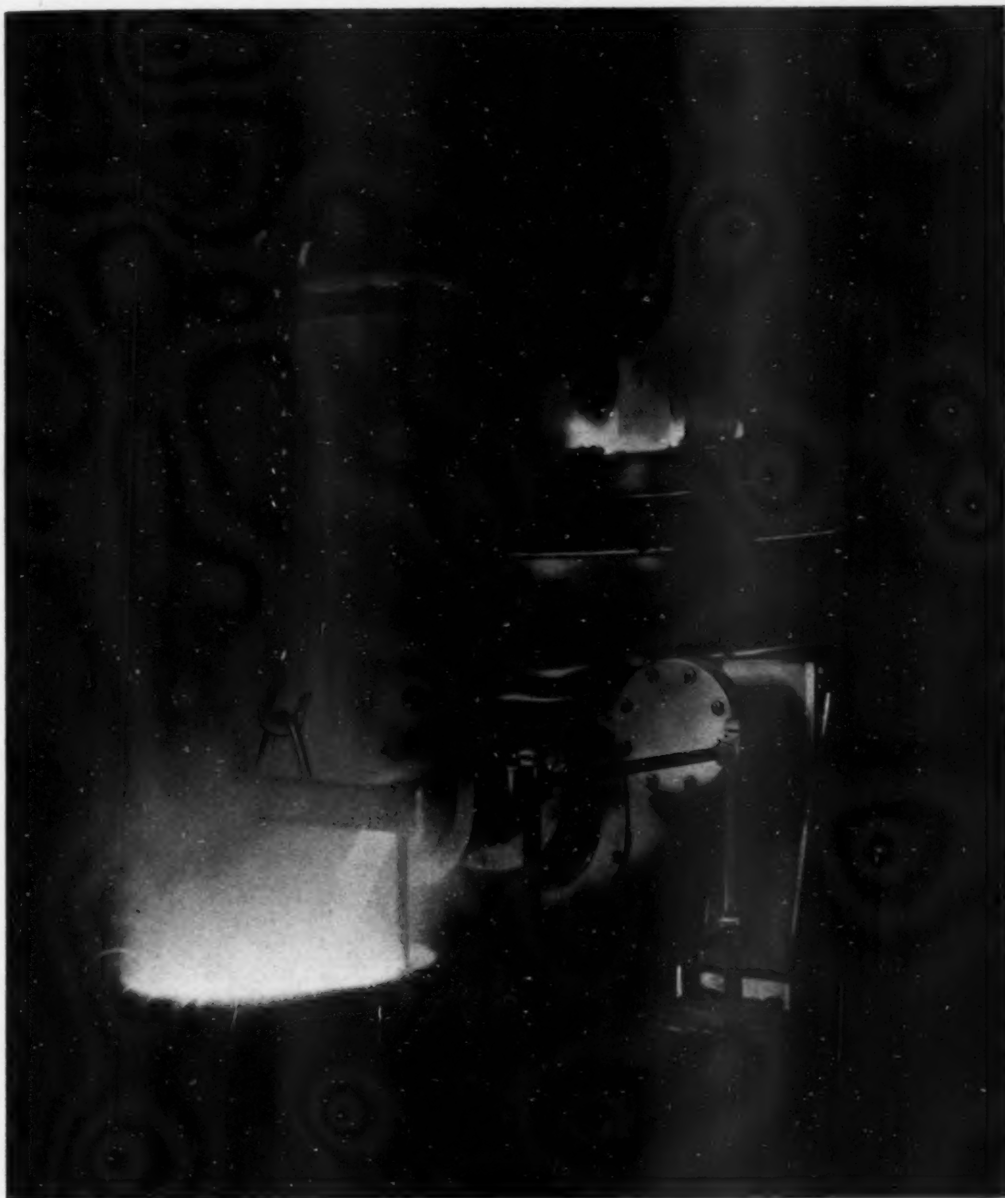

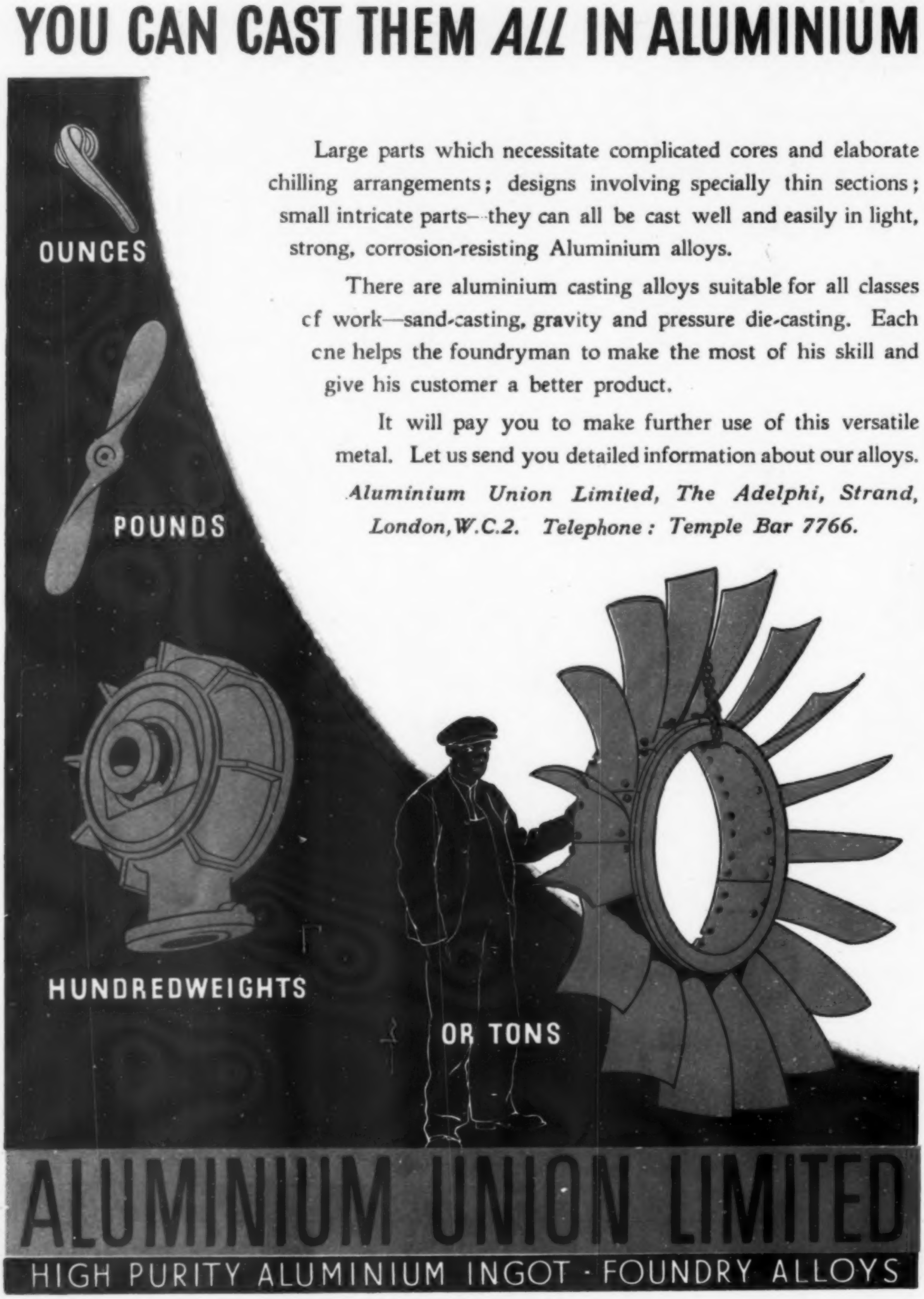
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INCORPORATING "THE METALLURGICAL ENGINEER".

FEBRUARY, 1939. VOL. XIX. No. 112.

Photomicrography in Colour

By W. F. Chubb, Ph.D. (Lond.), B.Sc.

The recently-developed process of colour photography is of value in metallurgical photomicrographic work, and in this article the author describes an adaptation of a known process to metallurgical needs. The underlying principles are briefly outlined, the handling of the film, its use and processing are discussed and some general notes given to assist in the application of the process.

THE procedure to be described is an adaptation of the Dufay colour process to metallurgical needs, but before giving an account of the technique of colour photomicrography, it would be as well perhaps to outline the underlying principles.

Film Manufacture

Photographs in colour were first demonstrated by Clerk-Maxwell, in 1861, but until the introduction of the Dufay process about two and a half years ago, the two processes available were either too slow or too difficult for the inexperienced photographer. These systems of colour photography were the screen-plate process, producing a colour transparency, and the colour separation process. Both procedures were based upon the properties of transparent filters in transmitting or absorbing certain of the colours in white light.

In the Dufay film, the filters are embodied in the film itself. The colour pattern, or réseau, is a transparent pattern of alternate blue and green squares and red lines, the complete colour pattern being reproduced 20 times per millimetre, or about 500 times per inch. In manufacturing the film, the base is first coated with a very thin layer of collodion which is dyed blue. Then, at an angle to the length of the roll, is printed a set of greasy ink lines with 20 lines to the millimetre, the spacing between these lines being exactly equal to the width of the lines. The dye between these ink lines is then bleached and the bleached portions of the pattern are then coloured green in a second dyebath. The next operation consists of removing the original ink lines thus giving a film with parallel green and blue lines which run diagonally across it. Further processing is then undertaken by printing a second set of greasy ink lines at right angles to the coloured lines, these lines being somewhat broader than the first set. Bleaching the film then removes the green and blue lines in positions where they are unprotected by the applied ink, and this treatment gives a pattern of green and blue squares crossed by clear lines, the latter being then dyed red. The ink lines are then removed and the pattern is protected by coating with a thin layer of varnish. The réseau is then coated with panchromatic emulsion.

Principles

To illustrate the fundamental principles it will be seen that light passing through the green squares is stopped by the blue and red. Hence, the silver bromide of the panchromatic emulsion is affected only by the light passing through the green squares, and is unaffected at those positions where the green light has been absorbed by the red and blue dyes. If now the film is reversed by suitable processing, it will be found that the emulsion existing at the back of the green squares is perfectly clear, and will thus transmit white light. At the back of the red and blue

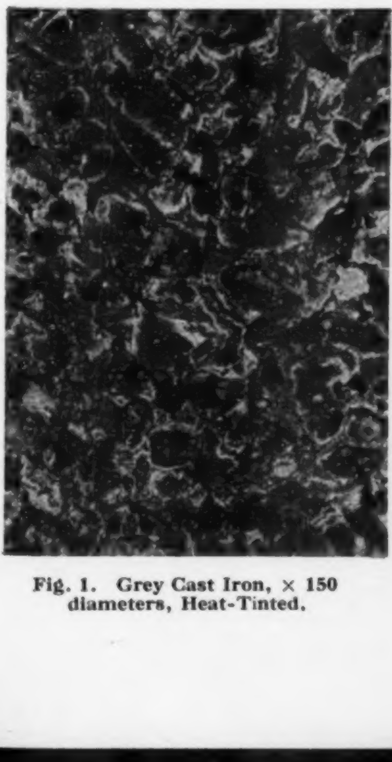

Fig. 1. Grey Cast Iron, × 150 diameters, Heat-Tinted.

Fig. 2. Grey Cast Iron, × 150 diameters, Heat-Tinted.

Fig. 3. Grey Cast Iron, × 500 diameters, Heat-Tinted.

squares, however, there will be an opaque black deposit. This means that, although no transmitted light can pass through the blue and red squares, it will pass through the green squares only. Since the pattern is very finely drawn, the film, if held up to the light, will give a continuous picture of the object in green. Also, light passing the red squares is stopped by the blue and green, and on processing gives a transparency of the original object in red. The action is in fact similar for all the three primary colours of the spectrum, and thus a transparency is produced representing the original object in natural colour.

Handling the Film

The loading and handling of Dufay film should preferably be carried out in total darkness, and owing to the extreme sensitivity of the emulsion it is necessary to ensure that no stray light enters the darkroom, the emulsion being sensitive to all the colours of the visible spectrum. It is possible, however, to employ a deep-green panchromatic safelight, but if this is used it should be arranged so that the light is reflected from the ceiling. The Dufay film must even then be kept away from the direct reflected light.

From the principles described it will be seen that Dufay colour films must be exposed through the base. If a roll film contained in a suitable adaptor is used in the camera extension, the film will automatically assume this position, but for metallurgical photomicrography flat film is much more convenient. In this case the base of the film can be recognised quite readily in the dark as it is smooth to the touch. The films are also supplied with a black-paper backing as a protection for the emulsion-coated side, and when loading the film into the carrier this paper should be adjacent to the carrier back. In handling the film care must be exercised to avoid the formation of finger-prints on the base.

There are three methods of loading flat film—viz.: (*a*) film holders or sheaths, (*b*) glass or cardboard behind the film, and (*c*) glass in front of the film. Film holders were used with the specimens illustrated, and may be obtained from photographic dealers. A convenient size of film for metallurgical work is 3¼ in. by 2¼ in. In loading the film holder the end of the film, to which is attached the backing paper, is inserted first to ensure that the emulsion is adequately protected from scratches, and that the paper cannot crease. If a film holder or sheath is not readily procurable, the Dufay film must be backed with a sheet of glass—e.g., old negative, or with good-quality cardboard, otherwise the darkslide springs are very likely to force the film forward when the sheath is withdrawn for exposing the film in the camera. It is essential to use a good quality cardboard or the emulsion is likely to be fogged if stored for more than a day under these conditions. The third method of loading the film consists of placing a sheet of glass in front of the film, but there must be no marks or dust on the glass. In this instance, it is necessary to re-adjust the focusing screen for the difference of register, and this is easily accomplished by reversing the ground glass screen in the camera extension, so that the matt surface is away from the lens system.

For small films such as those mentioned, or for any size up to half-plate, all these methods are suitable.

Photography

The general technique employed in monochromatic photomicrography applies also to Dufay colour film, but there are certain essentials to be observed. Firstly, to ensure the best possible colour rendering a compensating filter must be used for the particular light source employed—e.g., arc lamp, low-voltage lamp of high amperage, or Pointolite. These compensating filters are of special character and are obtainable only from the makers of the film, Messrs. Dufay-Chromex, Ltd., Elstree, Herts. They are devised to suit each batch of film produced, and thus a filter suitable for one batch is not applicable to another batch. It is therefore essential when ordering flat film to specify the light source to be employed, or when ordering filters separately, the batch number of the material, which will be found on the box, must be quoted. A filter about 1¼ in to 1½ in. in diameter is convenient for use with most of the photomicrographic equipments now available.

The compensating filter must be placed in the optical system, but although its position is largely immaterial, it should preferably be arranged as close as possible to the microscope sub-stage. There are, however, two positions in which the filter must not be used, for being of gelatine, it must not be mounted on the lamp housing unless protected by a heat-absorbing filter or trough, and it must not be placed in such a position that only a small area of the filter is in actual use—e.g., at or near the focus of a condensing lens.

In monochrome photomicrography, when photographing differentially-coloured specimens or objects, it sometimes happens that two widely different colours give the same photographic effect in that they produce equal blackness on the negative. The use of colour filters for suppressing or accentuating one of the colours thus becomes essential, but when making a photomicrograph in Dufay colour these contrast filters are quite unnecessary as the film retains the actual colour differences.

The use of achromatic objective and Abbe condensers may cause slight colour fringes around any sharply-defined edge, such as sharply-defined cellular structures, but the use of apochromatic objective and condensers and compensating eyepieces should eliminate this trouble.

It will be clear that the Dufay colour process is not only of value in metallurgical photomicrographic work, but that it is applicable also to botanical, histological and pathological uses. Very striking examples can be obtained by the use of dark-ground illuminators, more particularly when differential illumination, as by the use of Rheinberg filters, is employed.

It will be found in practice that exposure times are a little longer than those normally used in monochrome photomicrography, and as a basis for subsequent work it is recommended that a film be exposed in strips to determine at a magnification of say, 100 or 150 diameters, the correct exposure time so that a calculation of exposures at higher magnifications can be made as required.

The processing of an exposed Dufay film consists of 12 stages. This sounds formidable, but five of them are rinsing operations. If the requisite number of dishes, each containing its appropriate solution, is arranged in proper sequence on the bench or table in the darkroom, the process can be carried out without hitch, and a finished photomicrograph in colour can then be obtained in under 30 minutes. The sequences are as follows:

First Development

This is a timed development undertaken in total darkness, and it takes three minutes at normal temperatures. The paper backing is removed from the film, and the developing solution must be kept moving all the time. A recommended developer is :—

Metol	3 grams.
Sodium sulphite crystals	100 ,,
Hydroquinone	6 ,,
Potassium bromide	2·75 grams.
Ammonia, sp.gr. 0·880	11 c.c.; or
B.P.	34 c.c.
Water to	1,000 c.c.

2. Rinse the film in water for 30 secs.

3. *Reversing Bath.* This operation also takes three minutes in all, but after the first 1½ minutes the white light may be turned on. If the high lights appear to have a foggy patch in them, this is a sign that the reverser is stale. A new batch of reversing solution should then be made, and the film transferred to it. A suitable reverser is one containing :—

Potassium permanganate	2 grams.
Potassium, or ammonium persulphate	0·5 ,,
Water to	1,000 c.c.
Concentrated sulphuric acid	10 c.c.

In making this reversing solution the usual precautions in adding the concentrated acid should be observed.

4. Rinse the film for 30 secs. in water.

5. *Clearing Bath.* The film is now cleared by transferring it to a metabisulphite solution containing :—

Potassium metabisulphite	25 grams.
Water to	1,000 c.c.

6. Rinse for two minutes in water.

7. *Fogging by Re-exposure.* The surplus water is removed from the film, preferably by shaking, and the emulsion side is exposed to the light of a 60-watt frosted lamp for a minimum period of $1\frac{1}{2}$ minutes at a distance of about 6 in. An over-exposure makes no difference to the results, but the time given above is an absolute minimum.

8. Second Development.

The second development may be undertaken in either the original developing solution or in a second developer of the following formula :—

Metol	1·5 grams.
Sodium sulphite crystals	150 ,,
Hydroquinone	12·5 ,,
Sodium carbonate crystals	100 ,,
Potassium bromide	2 ,,
Water up to	1,000 c.c.

The time of development at ordinary temperatures is four to six minutes.

9. Rinse in water for five minutes.

10. *Fixing and Hardening.* The time required for fixing and hardening is five minutes, and a suitable solution is one containing :—

Hypo	300 grams.
Potassium metabisulphite	25 ,,
Chrome alum	12·5 ,,
Water to	1,000 c.c.

In making this solution the hypo is first dissolved in about 500 c.c. of hot water, the metabisulphite is next added, and the solution is allowed to cool. The chrome alum is dissolved in about 200 c.c. of warm water, and added to the above solution, the bulk being then made up to 1,000 c.c. with water.

11. Wash the film for 30 min. in running water.

12. The final operation consists of wiping off the surplus water with either a viscose sponge or with a good-quality chamois leather, and then drying in a dust-proof place.

General Notes

The use of development frames, though not essential, is to be recommended.

When making up the developer, the sulphite should be weighed out first, and about six grams dissolved in about 500 c.c. of water, which should be warm. The metol should then be added, then half the remaining sulphite, and when dissolved, the hydroquinone. Finally, the remaining sulphite is added.

It is preferable to filter the solutions through cotton wool immediately before use. The solution used in the first development will, however, keep well provided that the ammonia is not added until just prior to use. If a quarter-plate dish is to be used, 100 c.c. of stock solution should be measured out, and to this 1·1 c.c. of 0·880 ammonia added. It is essential that this volume of ammonia be measured accurately, and that it should not be added to a solution that is over 32° C. The developer may therefore require to be cooled before addition of the ammonia.

The film should be placed emulsion side upwards in the developer, and the dish rocked in all directions. The film must, of course, be completely immersed in the developer.

Results

The three photomicrographs reproduced herewith illustrate the results obtained. No. 1 (at a magnification of 150 diameters) is of a cast-iron specimen which was heat-tinted to blue-violet. In photographing with the carbon arc and Dufay filter D-2/5, the exposure given was $1\frac{1}{2}$ seconds. This structure needs no detailed description, as it will be familiar to metallurgists.

Photomicrograph No. 2 shows a similar piece of cast iron, heat-tinted, however, to a lesser extent, the exposure (at a magnification of 150 diameters) being in this instance one second. A comparison between the two will reveal the colour latitude of the Dufay colour process.

Photomicrograph No. 3 (at a magnification of 500 diameters) illustrates the phosphide constituent in the second specimen of cast iron.

Other results have also been obtained. For instance, it has been found possible to photograph at a magnification of 1,200 diameters, and in the case of oxygen-bearing copper to record the oxide inclusions, which at the magnification mentioned are red, although they appear blue at low magnifications. A particuarly interesting result obtained was that of a piece of high-purity copper which was first etched to develop the grain boundaries. It was then exposed to the atmosphere over a weekend, when the different rates of attack between differently-oriented grain could be clearly seen since the colours produced ranged from the copper colour of unattacked grains to an almost mauve colour for deeply-tarnished grains. The change of colour at the grain boundaries was quite sharp with specimens which had been corroded beyond a certain degree. It was, however, observed that in slightly tarnished specimens of copper the central portions of the grain were attacked more than the material adjacent to the grain boundaries, this fact being clearly observed at suitable magnifications by a striking difference in colour.

Finally, a word may be said about under-exposed and over-exposed film. Although this process is very simple, a certain amount of experimenting is required before the technique can be mastered completely. During this experimental stage, when the chief difficulty is that of determining the correct exposure for any given subject, it is inevitable that mistakes will be made. The difference between an under-exposed film and an over-exposed film, as well as the essentially recognisable characteristics of both, can, however, be obtained simultaneously by first exposing a film strip by strip with increasing times of exposure. It is suggested that, as a preliminary experiment, the exposures given should be one, two, four, eight and 16 secs., when, after processing the film according to the procedure described, it will be seen that under-exposed strips will be too dense and lacking in colour contrast, and over-exposed strips be thin, facts which will be readily understood from the principles of the process.

Utilisation of Sulphur Contained in Smelter Smoke

The conversion of waste material, which may be somewhat of a nuisance, into a marketable mineral product is the object of a study being conducted by the Bureau of Mines, U.S. Department of the Interior, designed to recover sulphur from smelter smoke. The specific problem is to devise means to reduce the amount of sulphur dioxide emitted from the smokestacks of mines and concentrating plants that sinter, roast and smelter metallic sulphides. Some of the smoke reaches the ground and has a more or less damaging effect thereon, and the problem is to extract the sulphur from the furnace gases before they reach the atmosphere outside.

One of the methods for extracting the sulphur, which may be recovered as marketable elemental sulphur or as liquid or solid sulphur dioxide, is to use some suitable solution to absorb the sulphur dioxide. The results of some experiments made on three of the most promising amines as absorbents are now available.* The capacities of these and other absorbing solutions are compared, but several factors, found only by large scale tests, enter into the choice of a suitable absorbent.

* Report of Investigations 3,415; copies may be obtained from the Bureau of Mines, Washington, D.C.

Ageing of Iron and Steel

THE influence of oxygen in solid iron or steel represents an important field which has received the attention of many metallurgists with varying results, as the quantitative determination of oxygen and the influence of small amounts of impurities have been the chief factors causing oxygen to have an unknown influence in solid iron. Great improvements have been made in the determination of oxygen, but to distinguish between solid solution oxygen and inclusion oxygen remains uncertain. The selection of the property of age-hardening, or ageing, as a means of studying the influence of oxygen in iron and steel has been made by A. B. Wilder,* and a series of experiments has been carried out on iron of high purity saturated with oxygen at 1,300° C., and at lower temperatures.

The age-hardening of iron and steel in the light of present knowledge depends on the formation of a super-saturated solution of a hard constituent in iron. This condition of super saturation may be brought about by heating iron to any elevated temperature in the region of maximum solubility and quenching, and this type of age-hardening is commonly called quench ageing. The condition of super-saturation, or instability, may also be brought about by cold working. Iron saturated, or unsaturated, with an age-hardening constituent may, by sufficient cold work, be placed in an unstable condition, when the age-hardening constituent in a suitably distorted space lattice acts as a super-saturated solution, otherwise no age-hardening is observed. This latter type of ageing is usually called strain ageing. Both types of ageing have been made use of in the investigation under discussion.

The materials used in the investigation consisted of two high-purity research irons, containing 0·005 and 0·001% of carbon and 0·09 and 0·10% of oxygen, respectively, an Armco iron containing 0·03% of carbon and 0·06% of oxygen, a wrought iron with 0·025% carbon and 0·09% oxygen, and five steels with carbon contents varying from 0·03 to 0·19%, and oxygen contents from 0·013 to 0·04%. The Rockwell hardness testing machine was used throughout the investigation, and the average of four Rockwell readings was converted to Brinell hardness. Heat-treatment was carried out on specimens ½ in. thick by 1 in. square, and cold-working was performed by making a Brinell impression, and changes in hardness were observed by taking a Rockwell reading at the base of the Brinell. The pure irons were treated in a vertical tube furnace with oxygen for 200 hours at 300° C., for 4 hours at 800° C., for 2 hours at 1,075° C., and for ½ hour at 1,300° C., followed in each case by quenching.

The results obtained after heating the two pure irons in oxygen at temperatures ranging from 300° to 1,300° C., and quenching, showed the irons to harden to a small extent. If oxygen was the only cause of quench ageing, the irons would have exhibited marked hardness changes, but the specimens quenched at 300° C. age-hardened to nearly the same degree as the remainder of the specimens. The original hardness after quenching, and before ageing, was about the same for all specimens of the first iron, which would indicate no ageing in the quenching bath, while in specimens of the second iron ageing occurred in the quenching bath. In general, neither iron showed quench ageing to the degree expected, and the ageing that occurred could not be satisfactorily explained on the basis of carbon.

Specimens of both irons quenched from the various temperatures, and cold-worked by the Brinell method, exhibited marked strain ageing, and from the results obtained it is probable that oxygen is responsible for the ageing obtained. The hardness after cold working and before ageing is quite high in several specimens, and this suggests ageing during the cold-working operation. The idea has been expressed that an iron-oxygen compound is precipitated upon the slip planes of cold-worked steel, and the data obtained support this theory.

Various heat-treatments were applied to Armco iron, and marked quench and strain ageing was obtained in all cases. The specimens quenched and cold-worked did not age harden to the extent of the combined effect of quenching ageing and strain ageing. This is explained upon the basis of ageing during the cold-working operation. The initial hardness of the cold-worked specimens is greater, due to the ageing during cold-working and the usual hardening effect of distorted and broken grains. The data obtained with the iron-oxygen alloys can be applied to Armco iron, carbon playing the principal role in quench ageing, and oxygen in strain ageing. The amount of strain ageing in Armco iron compares favourably with the strain ageing that takes place in annealed iron-oxygen alloys.

The wrought iron and four low carbon steels, 0·03 to 0·04% carbon, with and without various deoxidisers, including aluminium, manganese and silicon were quenched and aged. Wrought iron, although high in oxygen, did not quench-harden to the same extent as the various steels low in oxygen. The steel deoxidised with aluminium exhibited less age-hardening than the other steels, and the hardness of this steel after quenching was greater compared to the other steels, which indicated ageing in the quenching bath and less quench ageing, as the actual grain-size of the various samples was quite similar. The age-hardening of the low-carbon steels is explained on the basis of carbon with oxygen playing a secondary part.

The maximum hardness obtained from the artificial strain ageing of the various low-carbon annealed steels occurs at different temperatures and time intervals. All these steels showed marked strain ageing, aluminium-deoxidised steel being no exception. It is also shown that the production of non-ageing steel does not depend upon the addition of a strong deoxidiser, although the conditions at the time of deoxidation are important, and a suitable heat-treatment of the rolled steel is usually essential. The final hardness values produced by artificial ageing are the same as, if not greater than, the results obtained by natural or room temperature ageing.

The results obtained from strain-ageing annealed and heat-treated special deoxidised 0·19% carbon steel show steel exhibiting no strain age-hardening to be produced by special heat-treatment after suitable deoxidation. Quenching from 900° C., and tempering at 650° C., produced a favourable condition contributing towards the non-ageing property of this steel. The properties of a non-ageing steel of the type discussed originate in the deoxidation practice, and it is believed that proper deoxidation in combination with heat-treatment produces a condition in steel that removes oxygen from a steel favourable towards strain ageing. Simple annealing of this steel, however, at 900° C. produces marked strain ageing after a small amount of cold-work. As the degree of cold-working increases to a certain point the degree of age-hardening increases, but greater applications of cold-work decrease the amount of strain ageing, until a point is reached at which it does not occur. This is explained by assuming that age-hardening occurs during cold-working, and the more severe the cold-working the greater the age-hardening during the operation. Provided the steel is not of a non-ageing type, the data obtained indicate that the hardness produced by cold-working is partially due to instantaneous ageing.

Experiments were also carried out on Armco iron, carburized and then heat-treated, when marked ageing occurred under certain conditions of treatment. Quenching ageing under such conditions is attributed to carbon, with oxygen as a secondary factor, and strain ageing to oxygen. Carburized specimens of Armco iron probably retain sufficient oxygen to account for the ageing observed, as high-carbon steels, low in oxygen, do not usually strain age-harden.

* *Metals and Alloys*, 1938, Vol. 9, No. 5, pp. 119-123; No. 6, pp. 145-148.

METALLURGIA

THE BRITISH JOURNAL OF METALS.

INCORPORATING "THE METALLURGICAL ENGINEER"

Industrial Activity

Influence of British Industries Fair

THE view is widely held that efforts to ensure a large measure of economic peace will eventually be successful, and this thought is giving a degree of hope to business people that is contributing to a more spirited view of industrial activity. But there is no direct evidence that industry is expanding; in fact, the last returns show the reverse to be the case. The value of exports in December was 10·9% below the figure for the corresponding month in 1937, and the decline was slightly above the average for the whole year. Machinery was the only item to show an increase, practically all other industries showed a fall which was most marked in the case of textiles, iron and steel, and chemicals. A sharp fall of imports is also noteworthy; this might be regarded as encouraging were it not that they indicate a falling off in home consumption of some raw materials. It is probable, of course, that when the January figures become available some evidence of industrial and trade recovery will be shown, but the unemployment figures issued for that month seem to remove any such hope, since they show an increase on the December total of 207,654. It is of interest to note that the decline in employment was mainly in building, public works contracting, certain branches of engineering, clothing, and printing industries, while in coal mining and iron and steel manufacture employment improved.

Considerable interest is being taken, both in this country and in Germany, regarding the arrangements for the forthcoming Anglo-German industrial negotiations. These are to begin at Düsseldorf at the end of this month, when representatives of the Federation of British Industries and of the Reichgruppe Industrie will meet. No attempt has been made to define the scope of the negotiations since it is probable that representatives of particular branches of industry will meet opposite numbers, but it is likely that some agreement will be reached which will assist the solution of many problems associated with international trade and that of Britain and Germany in particular. The recent agreement between the coal industries of the respective countries can profitably be extended to other industries, and we shall be interested to see how much such negotiations will promote economic peace.

The immediate prospect for an expansion in exports is not particularly bright, despite agreements which have been entered into by the Government with several countries. Many countries are still reluctant to pay due regard to the sanctity of contracts, and, apart from political considerations, cause a want of confidence in trade generally. It is undoubtedly true that the uncertainties of the international situation do not reduce the difficulties, however the Government is fully alive to the position, and the recent Anglo-German Transfer Agreement and the subsequent supplementary agreement constitute a permanent settlement of the German Reich, which is an outstanding achievement, but countries should realise that a reputation for fair dealing is bound to pay a country in the long run.

One factor which will undoubtedly assist an early recovery in trade is the British Industries Fair, which opens on February 20, at Olympia, Earls Court, and Castle Bromwich. It is understood that buyers from sixty-six countries have intimated their intention of visiting this Fair, and there is every indication that the interest of foreign buyers is greater this year than in preceding years. This is by far the largest display of entirely national manufactures held in any part of the world, and in addition to showing the wonderful resources of the British Empire, it emphasises the scope, quality, and workmanship of British products.

The potentialities of this Fair for increasing trade are generally recognised, and with the political situation somewhat eased, exhibitors may well anticipate a busy time. But the contacts between manufacturers and potential buyers, which this Fair promotes, are of great value, even though orders may not be placed immediately. We know of several cases where exhibiting firms have received inquiries regarding particular products years after their exhibition at previous Fairs, which have led to substantial orders. This concentration of British industry gives the potential buyer an opportunity of seeing at first hand the advances in science and the arts, and to this extent the Fair can be regarded as a useful guide to progress.

Elsewhere in this issue an effort has been made to review some of the outstanding features of the heavy industries section at Castle Bromwich. Apart from improvements in products resulting from research, it will be appreciated that the display of manufactures in the various fields tends to effect improvements in the workmanship and finish of those exhibited; these improvements are a contribution to the general advancement, and the information regarding many exhibitors, published in this issue, will assist visitors with limited time at their disposal.

There is at least one industry to which the check on expansion does not apply—the aluminium industry. This industry is growing at a very rapid rate. In this country consumption of aluminium last year reached the record figure of 65,000 tons, an increase of 35% on the 1937 total and of 88% on that of 1936. A considerable proportion of these requirements is imported, in the form of ingots, blocks and billets, mainly from Canada. Imports reached a total of 45,000 tons, compared with 31,500 tons in 1937. Production in this country is also increasing, however, and early last year the British Aluminium Co., Ltd., put into operation the first part of their Lochaber extensions, while later in the year the whole of the extensions were in operation. The present increased output of this company is being readily absorbed. The favourable position of this industry is largely due to heavy commitments in aircraft production, an industry in which Britain now rapidly forges ahead, but new uses for aluminium and its alloys are contributing to the period of prosperity this industry is experiencing, and some indication of the progress in this field, in which many countries have contributed, is given in the Aluminium Supplement published with this issue.

Although the prospects of immediate improvement in more general industrial activity are not bright, the combined influence of increased rearmament and A.R.P. expenditure, together with a continuance in the recovery of the United States, should shortly result in an upward trend. Certainly the former should be used to absorb much of the idle manpower, while the latter, by stimulating world trade, will tend to improve the position for British exports.

Photography and the Microscope

THE first person to suggest definitely the use of a substance sensitive to light, in order to make use of light in recording objects, was Thomas Wedgwood, fourth son of the famous potter. According to a paper by Sir Humphrey Davy, in 1802, he rendered paper or leather sensitive to light by soaking in a solution of silver nitrate, and made copies of various objects by laying the sensitive paper behind them and exposing to light. But he could find no means to preserve the image in daylight. It was not until 1839 that photography, as a practical art, had its birth. It was then that the inventions of six independent investigators became known—namely, Joseph Nicéphore Niepce, Jacques Louis Mandé Daguerre, William Henry Fox Talbot, the Rev. J. B. Reade, Hippolyte Bayard, and Sir John Herschel. It is believed that Herschel coined the terms "photograph" and "photography."

During the hundred years that have followed there have been many inventions that have influenced mankind, but it is doubtful whether any has had a greater influence than photography and the developments associated with it. Apart from the almost universal participation in this art, it has become indispensable to science. It is of great value, for instance, in giving a permanent picture of matter examined under the microscope, and it was this art which assisted Dr. Sorby in his study of the structure of certain metals with the microscope just 75 years ago.

As the practice of the art of photography developed, efforts were made to reproduce colour as seen in nature. It was known that there were three primary pigment colours which would reproduce almost exactly the colours in nature, and between 30 and 40 years ago a method of photographing a scene in these colours was developed. It was found that three exposures were necessary, each one of which was made by cutting off two of the primary colours in light, which, of course, is itself made up of all three colours. These exposures were then developed in red, yellow and blue and superimposed to provide the natural colour of the object or scene photographed. This method has also been used to reproduce the microstructure of metals in colour, it is therefore particularly appropriate that a new method of producing colour photomicrographs should be described in this issue, and some examples reproduced in colour.

Planned Electrification

THE importance of a carefully-planned scheme for the efficient use of power is admirably shown in a film released by the Metropolitan-Vickers Electrical Co. Ltd., the première view of which was presented recently in the Central Hall of the Research Department of the Company. Made by Messrs. Publicity Films Ltd., working in close conjunction with the Metropolitan-Vickers Mining Department, this film depicts the complete electrification of a modern Lancashire colliery, including the provision of skip winding and up-to-date cleaning and picking plant. Figures are given in the film to reveal the extent to which this modern electrification scheme has improved the output of the mine both in the quantity of coal delivery and the manner in which this is handled.

An interesting feature is that the making of the film has been spread over three years, so that it includes shots of the colliery as it was before the scheme was commenced, the construction and installation of the new equipment, and finally a concise technical description of this equipment and the manner in which it operates.

The film is available for showing in technical colleges, institutions and any other places where the subject would prove of interest. Applications should be made direct to the Mining Department, Metropolitan-Vickers Electrical Co. Ltd., at Trafford Park, Manchester.

Forthcoming Meetings

INSTITUTE OF METALS.

Birmingham Section.

Mar. 2. Selection from Institute Papers.

London Section.

Mar. 2. "New Methods of Working Metals," by C. H. Schneider.

North-East Coast Section.

Feb. 23. Joint Meeting with Newcastle Section of the Society of Chemical Industry.

Mar. 14. "Die-casting," by G. E. Lewis.

Scottish Section.

Feb. 20. Joint Meeting with the Institution of Automobile Engineers, Scottish Centre.

Mar. 13. Selection of Institute Papers. Annual General Meeting.

Sheffield Section.

Feb. 22. "Metals of High Purity," by C. H. Desch, D.Sc., Ph.D., F.R.S.

Mar. 10. "The Tarnishing of Silver and its Prevention," by L. E. Price, Ph.D., M.A., and G. J. Thomas, Ph.D., B.Sc.

MANCHESTER METALLURGICAL SOCIETY.

Mar. 1. "Modern Methods of Melting Grey Iron in the Foundry," by Stanley E. Dawson.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

Mar. 10. "The Organisation and Equipment of a Shipyard for Welding," by Dr. W. Scholz. (General Meeting at Newcastle.)

Feb. 20. "Development of the Poppet Valve Steam Engine," by John Ferguson. (At Sunderland.)

Feb. 16. "Welding in Structural and Shipbuilding Work in America," by R. M. Gooderham, B.Sc.

STAFFORDSHIRE IRON AND STEEL INSTITUTE.

Mar. 7. "Fuels and the Metallurgical Industry," by Dr. S. G. Ward.

ROYAL AERONAUTICAL SOCIETY.

Mar. 2. "Testing Stability and Control of Aeroplanes," by Dr. A. G. von Baumhauer.

INSTITUTE OF BRITISH FOUNDRYMEN.

Birmingham Branch.

Mar. 3. "Some Views on Cast Iron for Enamelling," by S. Evans, M.Sc.

East Midlands Branch.

Feb. 25. Annual Dinner (at Loughborough).

Lincolnshire Section.

Mar. 13. "Examples of Practical Moulding," by F. G. Butters.

Lancashire Branch.

Mar. 4. "Rejects and Replaces in the Brass Foundry," by W. Machin.

London Branch.

Mar. 8. "Molybdenum in Cast Iron," by W. F. Chubb, Ph.D., B.Sc.

Middlesbrough Branch.

Feb. 17. "Fifty Years' Progress in Steel Moulding," by F. Swift.

Mar. 10. "Statuary Castings," by H. Foster.

Newcastle-on-Tyne Branch.

Feb. 25. I.—Works' Visit.
II.—"Report of Cast Iron Sub-Committee upon the Properties of Cast Iron," presented by E. B. Ellis.

Scottish Branch.

Mar. 11. I.—"Nickel in the Non-Ferrous Foundry," by F. Hudson.
II.—Annual General Meeting.

Falkirk Section.

Feb. 27. "Cupola Control," by H. P. Hughes.

Mar. 13. "Thirty Years of Progress in Cast Iron," by A. B. Everest, Ph.D., B.Sc.

Sheffield Branch.

Mar. 2. "Foundry Drying and Core Shop Layout," by W. H. Smith.

Wales and Monmouth Branch.

Feb. 25. "Some Factors in the Production of Electric Steel Castings," by J. G. Gist. (At Llanelly.)

Mar. 11. I.—Annual General Meeting.
II.—"Patternshop and Foundry Problems," by T. R. Harris.

West Riding of Yorkshire Branch.

Mar. 11. Open Discussion on Foundry Problems.

Industrial Management and Production Control

Part V.—Application of Wage Systems in Metallurgical Works

By F. L. Meyenberg

The wage system employed in any works is of fundamental importance in maintaining a spirit of real co-operation between the management and the men, which has such an influence on the prosperity of a firm. In this article systems in operation in metallurgical works are discussed, particularly the tonnage bonus system which is frequently used in ferrous and non-ferrous works.

Tonnage as Measure

At the end of the last article I pointed out that the tonnage bonus system, so frequently used in ferrous and non-ferrous metallurgical works, has its deficiencies; but the problem is more involved than could be indicated in those closing remarks.

In metallurgical works it is customary to speak of the output of a furnace, a rolling mill, a machine tool, etc., in tons, together with superficial characteristics that may be allowed; but every production engineer knows that this term can only be taken as a real measure if the kind of tonnage, determined by quality, dimensions, etc., is, at the same time, clearly defined. Of course everyone appreciates this fact; but how often is it done in daily practice? The mill manager asks the foreman why the mill has produced only 420 tons this week, against an average of 500 tons during last year. The workmen ponder on Friday morning that *more* than $1\frac{1}{2}$ days' work are necessary during the running week to reach "their earnings." The salesman and the controlling cost accountant grumble that again the mill has not done its duty during the past week, because it has not done its average tonnage, etc.

That, of course, is all wrong, and everybody knows it; but the habit has grown to such an extent that it can rightly be spoken of as an illness of the mind, a "ton-psychosis," and its seems to be opportune, under present working conditions, involving stronger competition and more strained labour relations, with the greater necessity for control of economy, to dispense with this thoughtless method of expression. I do not exaggerate by stating that much greater success will result from a saner method of measuring, or at least the adoption of the best possible one. It would clear the whole atmosphere in the works and remove the reason of much misunderstanding and heated discussions between the persons concerned, and the methods of planning and progressing, of costing and controlling, would be simpler and cheaper.

What are the methods of measurement which could be used instead of the actual weight expressed in tons? There is, first of all, the *working time*, secondly, an "*equivalent ton*," a term which will be explained later, and thirdly, a combination of both.

Working Time as Measure

We need only study the interesting report of the Rolling Mill Committee of the Iron and Steel Industrial Research Council, as published by the Iron and Steel Institute,* from which we will see how great the difference is when using time instead of tonnage as measure. I take out at random from tables of cogging times of three different types of ingots on pages 44, 45, and 46 of this report the figures given in Table 1.

A cogging performance card from page 50 of the report is shown in Table 2. It indicates how these figures are used for building up a report from which the efficiency of the shift can be seen. Of course, this report could also be made out using tonnage figures instead of time, and considering it separated from reports of other shifts, no advantage seems to be evident by the one method against the other. Assuming, however, that the mill had to roll, instead of the mixed programme as indicated by Table 2, 105 ingots, type W.P., $7\frac{3}{4}$ in. $\times$ $7\frac{3}{4}$ in., on the one hand, and 34 ingots, type S_1, $3\frac{1}{2}$ in. $\times$ $3\frac{1}{2}$ in., on the other hand, the total standard cogging times would be nearly the same in all three cases as $105 \times 2{\cdot}9 = 34 \times 9{\cdot}0$ approximately 305 mins. Obviously, the performances of the three shifts would be equal too, but the outputs would differ very much:—

TABLE 1.

Type of Ingot.		Size of Blooms in In.		Weight of Ingots, Tons.	Cwt.		Rolling Times, Secs. or Mins.
W.P.	..	$7\frac{3}{4} \times 7\frac{3}{4}$	..	2	7	..	$174 = 2{\cdot}9$
S_1	..	$10 \times 4\frac{1}{2}$	..	3	2	..	$276 = 4{\cdot}6$
X	..	$10 \times 4\frac{1}{2}$	..	2	5	..	$210 = 3{\cdot}5$
S_1	..	6×5	..	3	2	..	$318 = 5{\cdot}3$
X	..	6×5	..	2	5	..	$252 = 4{\cdot}2$
S_1	..	$3\frac{1}{2} \times 3\frac{1}{2}$	..	3	2	..	$540 = 9{\cdot}0$

	Tons.
1. 105 ingots, W.P. $7\frac{3}{4}$ in. $\times$ $7\frac{3}{4}$ in., each $2{\cdot}35$ tons .. =	247
2. Performance according to figure 9 .... =	$195{\cdot}5$
3. 34 ingots, S_1 $3\frac{1}{2}$ in. $\times$ $3\frac{1}{2}$ in., each $3{\cdot}1$ tons ..... =	106

It will be agreed that these output figures are greatly misleading in judging the mill work, and even if it must be admitted that we have selected extreme cases and that the differences will not usually be so great in practice, these cases are by no means impossible.

What would the result be if these output figures were made the basis of future consideration? In planning beforehand the possible output of the mill according to average figures, perhaps represented by the performance card (Table 2), it will be noted that case 1 would take over 10 instead of 8 working hours, and case 3 only $4\frac{1}{2}$ hours. If these three shifts were worked one after another during one day in the morning, afternoon and night, and a tonnage bonus was paid separately to each shift, the morning shift would earn 26% more, and the night shift 45% less than the average represented by the afternoon shift. And yet the performance of all three shifts is nearly equal, showing that the men have worked with the same efficiency in each. But wrong results would also be shown in calculating the costs per ton if based on the output figures alone.

Of course, this difficulty is quite well known in many works, and methods are used to overcome it, either by pooling the earnings of the three shifts, or by paying an hourly fixed rate to the men, and in addition a correspondingly smaller bonus per ton, thus making the unfair manner of payment less obvious.

But why make this procedure so complicated if a simple way, clear to all concerned, is so obvious—i.e., using the rolling times, determined by proper time studies or any statistical method, as basic figures for planning, payment of wages and costing purposes? The men, especially, will soon recognise the fairness of this method, and be grateful for preventing fluctuations of their earnings associated

* cf. METALLURGIA, vol. XVIII, May, 1938, pp. 31, 32.

TABLE 2.—COGGING PERFORMANCE CARD.

Date.	Shift.	Foreman.	Tonnage Rolled.	Yield.	Overall Performance.	Cogging Performance.
Nov. 5th, 1936.	6/2	B	195–9	22·0	67·1%	90·2%

No. and Type of Ingot Cogged.	Size of Blooms Made. (Ins.)	Areas of Blooms Made. (Sq. Ins.)	Standard Times per Ingot. (Mins.)	Total Standard Cogging Times. (Mins.)
6 W.P.	$7\frac{3}{4} \times 7\frac{3}{4}$	60	2·9	18
37 S1	$10 \times 4\frac{1}{2}$	49	4·6	170
6 X	$10 \times 4\frac{1}{2}$	49	3·5	21
15 S_1	6×5	30	5·3	80
1 X	6×5	30	4·2	4
1 S_1	$3\frac{1}{2} \times 3\frac{1}{2}$	12	9·0	9

Booked Delays.	Mins.	% of Working Time.
Heat		
Mechanical and Electrical	50	11·1
Waiting Mill	55	12·3
Charging Cold Bloom		
Steam		
Re-cogging Blooms	10	2·2
Other causes		
Total delays	115	25·6

Weight cogged	195·9
Blooms made	175·12
Billets made	2·7
Blooms re-rolled	—
Tons per hour (over shift)	26·1
Tons per hour (ex delays)	35·0
Yield (cwts. per ton)	22·0

INGOTS CHARGED.	
Hot	—
Black hot	—
Cold	60
Pre-heated	6
Total	66

SUMMARY.		
Working time (shift time—meal time)	450	100
Actual cogging time (working time—delays)	335	74·4
Standard cogging time	302	67·1
Lost time (actual—standard)	33	7·3
PERFORMANCE.		
During cogging (standard/actual)	90·2	
Overall (standard/working)	67·1	

Remarks

with the old method, fluctuations not due to their working efficiency, but mostly caused by circumstances outside their influence, especially, for instance, the composition of the mill programme.

I would not like to conclude this example, however, without raising the question: Is this kind of work, the team work at one of the big rolling mills, really that sort of work which one has to consider as a proper job for any method of payment by result? It should be considered, that the mill itself is, to a great extent, the governing factor of the output, that, as already mentioned, the composition of the mill programme has a great influence, that the nature of the work calls for a strong supervision, and therefore, as far as possible, for the avoidance of delays. Is this not one of the cases, mentioned in our last article, where a return to a fairly fixed hourly rate would be the right way, removing many reasons for unpleasant discussions with the men, and—what is often forgotten—much clerical work?

I leave the answer open, as I know that there may be reasons for keeping to the present custom; but, if that is the case, the step from the unfortunate tonnage bonus to a fair piecework rate based on time should be taken under all circumstances.

The example of the rolling mill is used, because it is one where the advantages of the above principles can easily be explained, but it may be repeated that similar considerations also apply to furnaces of any kind, to many apparatus in chemical factories, to some machine tools, etc. To this last case we will come back later.

The "Equivalent Ton" as Measure

Sometimes it seems to be useful to keep to the habitual expression of tonnage as a measure of output, etc. Then it is necessary to modify at least the pure weight-ton in such a manner that the different kinds of tons produced—i.e., the tons of different value, can be added up without obvious mistake. One special kind of produced tonnage is taken as a basic figure, perhaps that kind, whose output used to be the greatest. The special properties of this kind of tonnage are carefully investigated in so far as they determine the value of a ton, the same is done with all other kinds of tons produced, and the figures of the individual properties are put into relation to each other, thus building up some factors, which allow the reduction of the value of each kind of ton to that of the basic ton, which is called "standard ton" or "equivalent ton."

I would prefer the second term, as the word "standard" has obtained a special meaning in its association with the work of the British Standard Institution, a meaning which indicates the importance of the standard product for a whole branch of industry, whereas we have to deal in this case with something important only for the individual works in question.

This working with equivalent figures is mainly used for costing purposes, but there is no question that it is also useful when projecting a new layout for a workshop or changing the old one, when planning the possible output, etc.

How this method is used may be shown by two examples taken from actual practice. The first refers to a constructional department of a big iron and steel concern. The production programme of this department was very variable; it changed between light constructions—e.g., light-posts where the wages formed a comparatively high percentage of the total costs, and very heavy constructions, as, for example, big river bridges. Careful statistics over a longer period showed that it would be useful and sufficient to divide the total products into six classes, according to the different influence of the wages to the total costs per ton. Taking the share of the wages in the Class I, with the lowest share equal to 100, those of the other five classes could be fixed with sufficient accuracy to always one-fifth more of the total difference between Class I and Class VI—i.e., to 116·6, 133·3, 150·0, 166·6, and 183·3. If, therefore, in an individual month the actual output in tons for each class was known, and Class I had been selected as basis—i.e., formed by "equivalent tons," the total output in equivalent tons could be determined easily as follows:—

	Actual Output in Tons.	Equivalent Figure.	Equivalent Output.
Class I	110·4	100	110·4
Class II	279·3	116·6	325·7
Class III	336·4	133·3	448·4
Class IV	356·7	150·0	535·0
Class V	218·1	166·6	363·4
Class VI	178·6	183·3	327·4
Total	1479·5	—	2110·3

Fig. 9 shows the result of this method of consideration during a period of 21 months, and the advantages of the method may easily be recognised. Whereas Curve 1, the material actually despatched, shows fluctuations which are partly inexplicable, the trend of Curve 2, representing the output in equivalent tons, is more steady; but that this second curve is really a better representation of the actual work of the shops can clearly be seen in comparing Curve 3 and Curve 4, showing the working time per despatched and equivalent ton. It is regrettable that the reproduction with the necessarily small scale cannot give clearly enough the fluctuations of Curve 4; as a matter of fact, in the original they indicate the improvement of the economy of the works at the end of this investigation, due partly to the higher output and partly to improvements in the shops based on observations during this investigation; this was carried out with the purpose of decreasing the transport costs and was very successful.

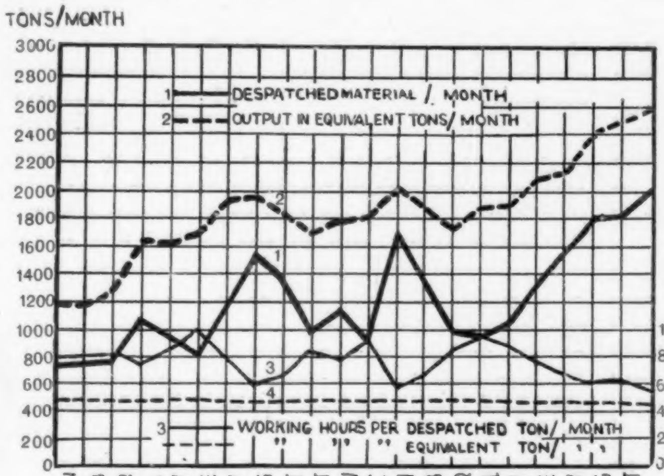

Fig. 9.—Output of the shop.

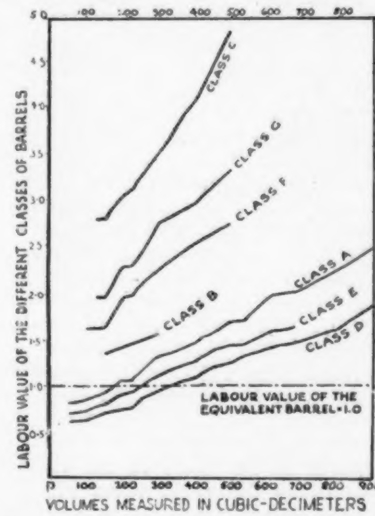

Fig. 10.—Labour values of different classes of barrels plotted against volumes.

The second example of the use of equivalent figures is taken from an investigation in a factory of iron barrels also connected with a big iron and steel works. In this case the problem was more complicated in so far as the more superficial treatment of classification as used in the first example would not have brought sufficiently accurate figures of comparison. On the other hand, it was fortunate that when starting the investigation equivalent figures had already been in use four years, and therefore sufficient figures of comparison were at hand to build up diagram Fig. 10, from which all necessary basic figures can be taken. As may be seen, seven different constructions of barrels were produced, and for each construction barrels of various volumes.

For comparison purposes, again the value of the necessary labour was taken, expressed in working minutes as determined by time studies for fixing fair piece-work prices; but not one actually produced barrel was used as a basis. In this case an "ideal barrel" was selected, using 60 working minutes, as in this way the basis will be constant, even if the working conditions of the "equivalent barrel" change and therefore the possibility of comparison over longer periods will be maintained. Lack of space prevents me from explaining more in detail how diagram Fig. 9 is built up, but I hope that the principle will be clear without further explanation. It is shown, in the investigation, how the equivalent could be used for the determination of a manning plan separately, in eight different shops occupied with the barrel production, for fixing correct dates of delivery, for daily control of output and production, and for building up production costs.

Finally, it may be mentioned that a third example for using working time as a measure and a basis of fair piece-work prices on the one hand, for applying equivalent figures for costing purposes on the other hand, taken from a wire rod mill plant, is published in detail in "The New Management," pp. 166 to 218. That may be sufficient proof of the applicability and usefulness of the methods recommended.*

Piece-work Prices at the Finishing Bank

It is usual in metallurgical works that the "hot" part of production, the melting shop, the hot rolling mill, etc., is succeeded by a "cold" part, mostly called a finishing bank. (These workshop terms may not always be correct; for in some cases, as, for example, in special steel works, hot processes, such as annealing, normalising, etc., are included in the work of the finishing bank.) Generally speaking, it is the job of the finishing bank to remove, as far as possible, certain defects of the material coming from the hot departments by annealing, chipping, pickling, straightening, etc., to put additional work into the material, according to the customer's orders, by sawing, shearing, or breaking to certain lengths, by milling or slotting, punching holes, etc., and to prepare the material for dispatch by carting, packing, bundling, etc. Here is the proper field of the piece-work wage system, but it is only too often here that old-fashioned methods of rate fixing are found, where the tonnage bonus system particularly exercises its fatal influence, since it is only in rare cases that the *weight* is one of the governing factors of the work, as, for example, with annealing. Usually the lengths, the cross-section, the quality of the material, the number of pieces ordered, etc., are much more important. Of course it is a much more difficult job, taking time and meditation, to consider all these various circumstances, but it is a job worth while doing, not only because it leads to fair piece-work prices—which the old method will never do—but because it clears the actual working conditions at the finishing bank to an extent unequalled before, thus inducing improvements of layout, procedure, and organisation.

It is not possible here to give an extensive guide as to how this job should be done, especially as the circumstances vary very much from works to works, but some hints and an example[1] may help.

As a rule, it is necessary to differentiate between setting time, main time, and lost time when calculating the total working time, and to consider each of these times separately in order to find the governing factors. Thus, for example, Fig. 11 shows the time in minutes per piece for straightening a certain section by a roller-straightening machine, plotted

* All three investigations were carried out in German industrial works and published under the personal responsibility of the writer of these articles.

1 Published in *Archiv fur das Eisenhuttenwesen*, vol. II, No. 6, pp. 303–306.

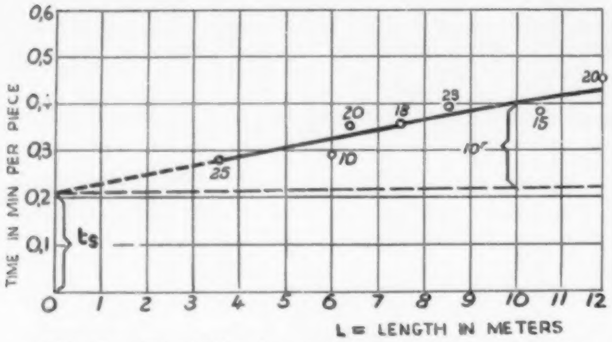

Fig 11.—Time T for the straightening of section X on a roller-straightening machine: $T = Lr + t_s$ min./piece.

against the length of the piece. This time is $T = t_s + r \times L$, t_s = setting time per piece, L = length of the piece, and r = the incline of the straight line which has been found by time studies for various lengths, the figures at the points showing the number of investigations on which these points for the various lengths are based. For Z pieces with a total length of y feet, the total working time will be time per foot $\times\ y$ + time per piece $\times$ Z. The incline will be nearly the same for similar sections—i.e., parallel lines will result, but will differ for different sections. In this way it is suggested that unavoidable lost time is included in the basic figures for t^s and r.

Often, however, it is necessary to repeat the straightening as performed at the roller-straightening machine, under a separate press, because the former does not work accurately enough, in which case a similar calculation must be made for this second straightening. As the costs for this press work are much higher, it is advantageous to give an incentive to the men to increase the accurateness of the roller straightening as far as they can. This can be done by determining how much of the roller-straightened material, measured in per cent. of the total, usually has to be straightened afterwards under the press, and to pay an increased rate for each per cent. saved in the actual press straightening. Both parts, the men as well as the works, will thus share in the profit.

Separating Material According to Orders

Even when the fair piece-work prices are determined there are some difficulties of organisation which must be overcome if they are to be applied according to the actual working conditions. Of these only two may be mentioned.

The first is to separate the material according to the orders to which they belong. The billets, rounds, slabs, plates, etc., may have different dimensions ; then a division is easy ; they may have different qualities ; then a division can and must be made, corresponding inscriptions either by painting or stamping, and if multiples of lengths are cut into pieces care must be taken that these inscriptions are repeated on each single piece. It may be that exactly the same products of similar dimensions and quality are required for different orders, and those inscriptions have to be added according to the orders. Experience has shown this to be possible throughout, but the workers often falsely regard it as "red tape," designed to reduce the actual work for which they are paid, and it needs strong supervision and the conviction of the men that this marking is part of their work, and the time necessary is calculated in the piece-work price.

It is doubtful whether this work of marking should be given to a special marking gang as then mistakes may creep in more easily ; in such a case the division of labour seems to be exaggerated.

Working on Day-work and Piece-work by Turns

The second difficulty arises if one is forced to insert work against a fixed hourly rate between piece-work from time to time. This cannot always be avoided, whether it is the work of rolling mills or machine tools, on the finishing bank. It is only natural that there is a tendency to increase the time of day-work on the records against that which is actually worked, although that is strictly speaking a fraudulent measure. The organisation should take care to avoid this by always handing out to the men only one order at a time. That, of course, is easier said than done, but no other method is known which keeps the survey over the work, ensures a real coincidence between the actual work and the records, or controls, whether the given piece-work rates are really fair. With these remarks, however, we touch the sphere of wage booking, which will be the subject of our next article.

(To be continued.)

A.S.T.M. Approve New Specifications Piping and Tubing Materials

IMPORTANT recommendations were approved as a result of the work of Committee A-1 on Steel, involving particularly the field of pipe and tubing materials. One noteworthy change was to issue revisions in the form of new tentative specifications to replace immediately the standard covering lap-welded and seamless steel and lap-welded iron boiler tubes. The new tentative specification is especially significant because the Committee has recognised the advantages of designating wall thicknesses by decimals in place of B.W.G. and fractions, as well as the desirability of indicating permissible variations for wall thickness and weight in percentages rather than by the existing dual system. The former grade of medium carbon material in the specification was deleted, and a new tentative specification for medium carbon seamless steel boiler tubes was approved. The use of this material and the desirability of making certain modifications in requirements indicated the necessity of a separate specification. The demand for recognised standardised requirements for carbon-molybdenum seamless steel boiler and superheater tubes resulted in new tentative specifications for this material. The close co-operation of consumers and makers resulted in a favourable consensus on the new specification.

For some time this Committee has been developing standardised requirements for spiral welded pipe, and there has now been issued a new specification covering spiral welded steel or iron pipe, 4 in. to 48 in. in diameter inclusive, with wall thickness from $\frac{1}{16}$ in. to $\frac{5}{8}$ in., manufactured by the following electric-fusion-welded processes : spiral lap-welded joint, spiral lock seam-welded joint, or spiral butt-welded joint. In order to cover spiral-welded material greater than $\frac{11}{16}$ in. in thickness, tentative revisions are being published in two existing specifications covering electric-fusion-welded steel pipe of sizes from 8 in. to 30 in., and sizes 30 in. and over.

Ferro-Alloys

Intensive work on the part of the Society's Committee A-9 on Ferro-Alloys, involving a complete review of nine existing specifications, resulted in a number of extensive changes and reissue in the form of new tentative standards. The Committee believes that the new specifications are truly representative of current commercial requirements. They cover the following : Spiegeleisen, ferro-manganese, ferro-silicon, ferro-chromium, ferro-vanadium, molybdenum salts and compounds, ferro-molybdenum, low-carbon ferro-molybdenum and ferro-tungsten.

Cathode Copper

To meet the demand for standard requirements for electrolytic cathode copper, new tentative specifications for this material were approved at the request of Committee B-2 on Non-ferrous Metals and Alloys. The quality requirements provide that the copper shall have a minimum purity of 99·90%, the silver being counted as copper. The copper is to have a resistivity not to exceed 0·15436 international ohms per metergram at 20 C. (annealed), the resistivity to be determined from a representative sample of each load, or 50 tons, as a lot.

ALUMINIUM INDUSTRY

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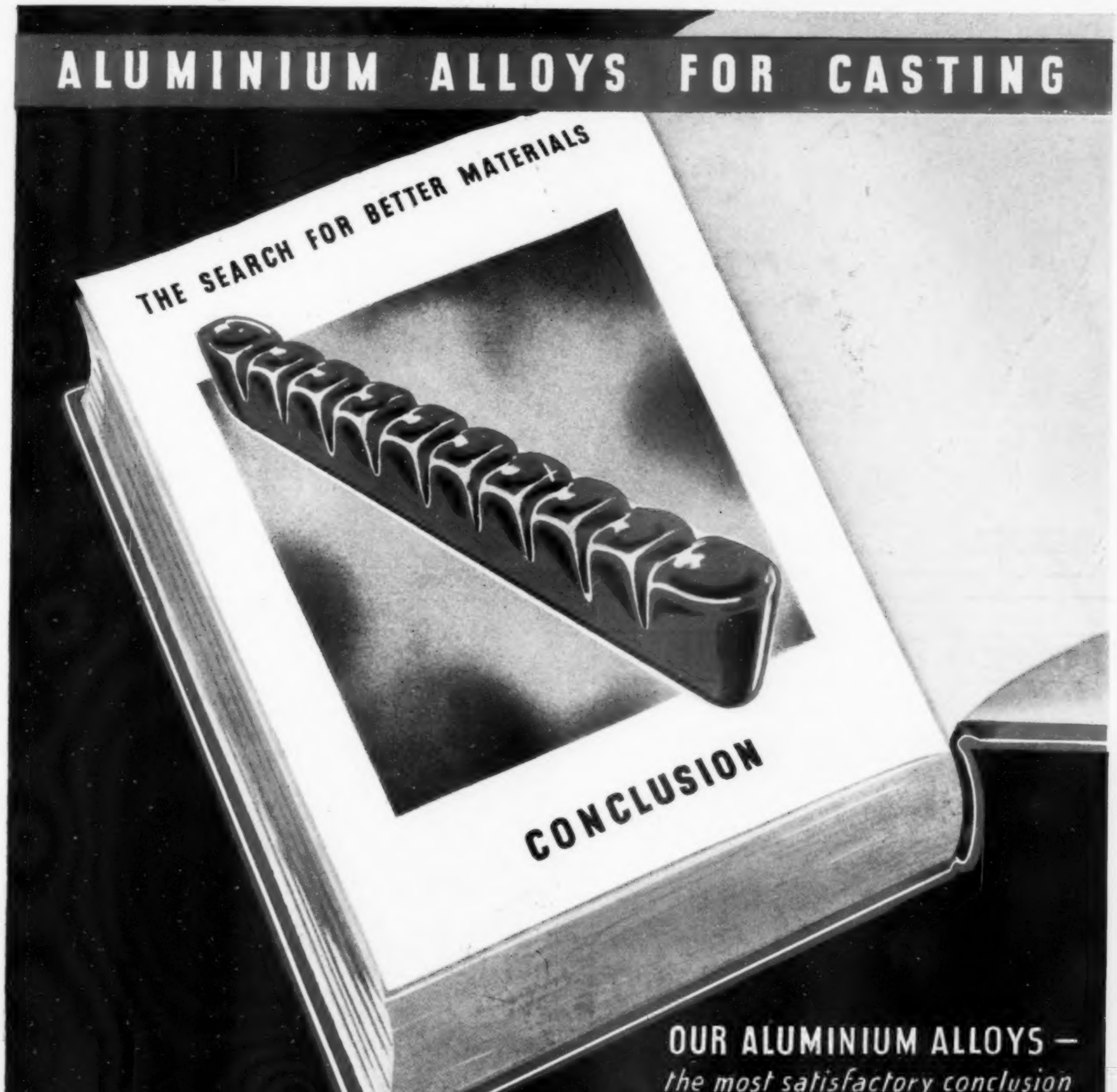
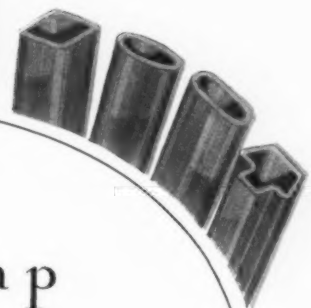
February, 1939 METALLURGIA Vol. XIX, No. 112





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Foreword

By **Dr. C. H. Desch, F.R.S.**

(Superintendent Metallurgy Department, National Physical Laboratory.)

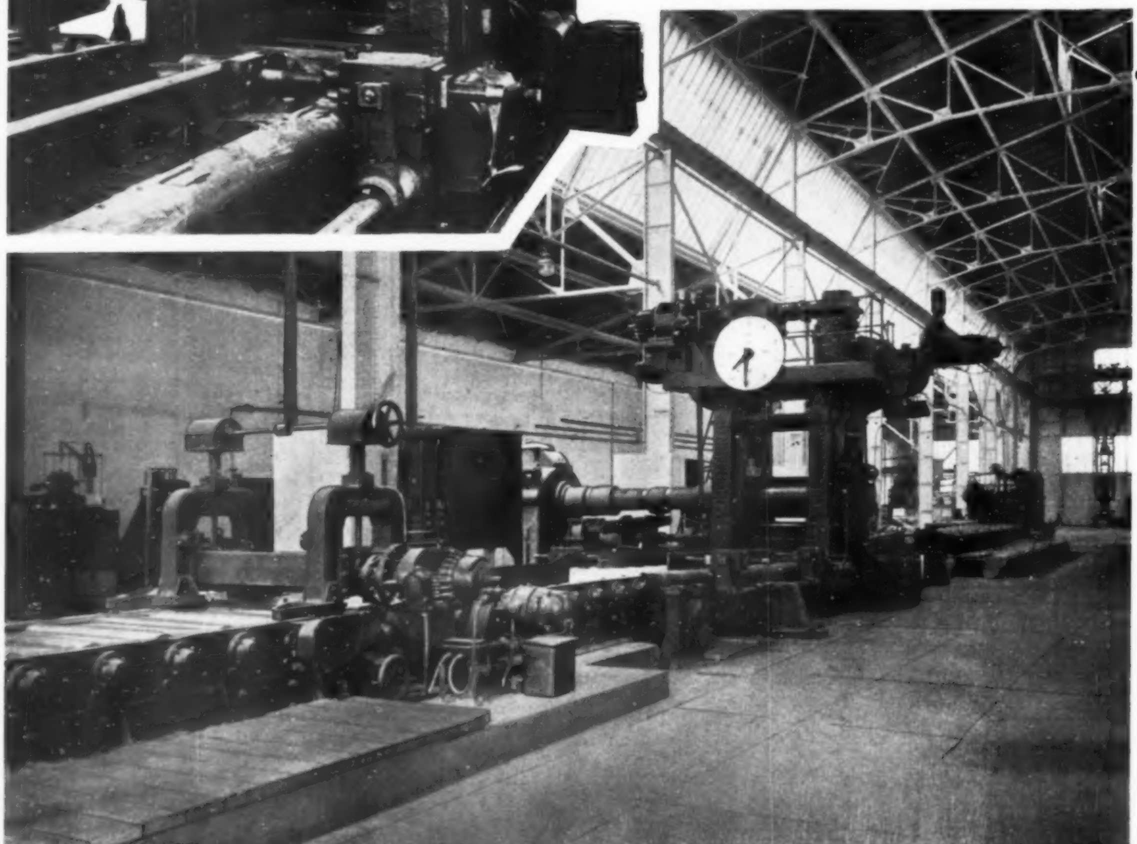
AMONG the striking metallurgical developments of recent years, the increasing use and range of the light alloys occupies a conspicuous place. The consumption of aluminium is rapidly growing, and its alloys are used for purposes which would have seemed unlikely a few years ago. To some extent this change has been due to the striving of certain countries after economic self - sufficiency, aluminium being a metal which can be produced where sources of cheap power, from water or from brown coal, are available. In Germany, as to which most information is obtainable, the light alloys, including those with magnesium as a basis, have been used for structural purposes for which only steel was formerly considered suitable. It would even seem that the regulated industrial policy has been pushed too far in this direction, as a recent article in the German technical press points out that light alloys have a field of usefulness which is distinct from that of steel, and that they should not be used as a substitute without a careful preliminary study of the conditions of service. On the other hand, the alloys of aluminium and of magnesium have to meet a new rival in certain fields, including that of aircraft construction, in the form of synthetic plastics, which have now been developed to such a degree as to compare with metals in strength and durabiltity.

C. H. Desch.

Few of the alloys having aluminium as a basis are used without some form of heat treatment, and the effects known as "age-hardening," first observed in duralumin about 30 years ago, are responsible for the production by heat-treatment of properties very greatly superior to those of untreated castings or forgings. The phenomena of age-hardening have proved to be unexpectedly complex, and the subject has engaged the attention of workers in many countries, using the resources of modern physical and metallurgical research. The main conditions which are essential in order that a given alloy may undergo age-hardening are generally known, but the relations between the several factors—chemical composition, temperature of quenching, temperature and time of ageing, and degree of mechanical deformation in the course of the treatment—provide a very complex series of problems. Hence, it is that in industrial laboratories as well as in those of public institutions, work is constantly in progress with the object of ellucidating some of these relations. It is not only necessary to find the conditions which give the best mechanical strength or resistance to fatigue or creep, but certain other properties, such as a liability to fail by intercrystalline cracking on exposure or under load, prove to be highly dependent on differences, sometimes remarkably small, in the heat-treatment given to the alloy. The early stages of the hardening process, involving considerable changes in mechanical properties but little or no perceptible alteration in micro-structure or in X-ray pattern, are of special interest for the understanding of the process. Recent work at the National Physical Laboratory has thrown further light on this stage. In continuation of former work by Gayler and Preston, a study of single crystals of certain aluminium alloys by means of X-rays has been made by Preston. Details in the X-ray pictures which had been overlooked by previous workers have been interpreted as showing the way in which the atoms of the dissolved element, such as copper, group themselves before the stage is reached at which a second solid phase can be said to be present, and this interpretation will prove of great assistance in explaining the mechanism of hardening. By one of those coincidences which are common in scientific investigation, very similar observations were made at the same time and independently by Guinier in France, who arrived at almost the same conclusions.

The commercial aluminium of to-day is often of remarkably high purity, when the activity of the metal is considered. Nevertheless, efforts have been made, and with complete success, to produce a "super-pure" metal by a process of electrolytic refining. In this product the impurities are in such small quantity as to call for spectrographic methods to detect them. When alloys were prepared in the laboratory from this highly-purified material, unexpected difficulties arose, age-hardening being more difficult to bring about. An investigation by Gayler, published during the year, showed that the cause lay mainly in the extreme softness of the pure metal, enabling it to flow during forging so easily as to fail to break up the particles of the second phase, which it is necessary to bring into solution in the subsequent heating process. The properties of such metal differ in a remarkable fashion from those of aluminium containing, say, 0·1% of impurities, and this fact opens up a new prospect in the study of the light alloys. Magnesium of similar purity is also available, and the remarkable fact is that these metals are purified on a commercial scale, and are not, as are most metals of exceptional purity, laboratory preparations.

The literature of the alloys of aluminium is very extensive, and continues to grow. The need for research is fully appreciated by the industry, and continued progress depends essentially on unceasing intensive study of the changes which proceed in the mass of an alloy during the



course of the processes to which it is submitted during manufacture and subsequent treatment (as in welding). Readers of METALLURGIA will be aware how greatly investigators in this country have contributed towards this end. The importance of the light alloys will increase still further with the progress of engineering, whilst at the same time the demands of the engineer for special properties, such as increased strength at high temperatures, become more stringent. The modern alloys could not have been arrived at by rule of thumb, and the research laboratory assumes more and more the position of the most essential aid to the advance of the industry.

Classification of Wrought Aluminium and Some Alloys for General Engineering Purposes

PURE ALUMINIUM—WORK-HARDENED.

Temper	Material.	Average Properties for 16–24 s.w.g. sheets.				Commercial Designation.
		Tensile Range, Tons/sq. in.	0·1% Proof Stress, Tons/sq. in.	Elongation % in 2 in.	Brinell Hardness.	
Soft	99% + Al	5·0—6·5	1·3	40	22	2L. 17
Half hard	,,	7·0—8·5	6·6	9	35	2L. 16
Hard	,,	9·25 min.	8·1	6	41	2L. 4

WROUGHT ALLOYS—WORK-HARDENED.

Type.	Major Constituents. (Balance Al.)			Temper.	Min. Mech. Properties.			Commercial Designation.
	Mg.	Mn.	Si.		U.T.S. Tons/sq. in.	0·1% P.S. Tons/sq. in.	Elongation % in 2 in.	
Al/Mn	—	Up to 1·5	—	Soft	6·5	—	30	BA/60 A
				Hard	13·0	11·0	3	D.T.D.213
Al/Si	—	—	11·0	Soft	9·0	—	20	BA/40 D
				Hard	12·0	10·0	5	
Al/Mg/Mn	Up to 3·0	Up to 1·5	—	Soft	11·0	—	18	BA/20
				Hard	16·0	14·0	5	D.2 Birmabright II D.T.D.209a 249
Plus Fe, Cu, Ni	3·0—6·0	Up to 0·75	—	Soft	14·0	—	20	Birmabright
				Hard	20·0	15·0	3	RR.66 D.T.D. 180a 170a
	6·4—10·0	Up to 0·6	—	Soft	20·0	—	20	M.G.7
				Hard	25·0	17·0	15	D.T.D. 182a 177a

WROUGHT ALLOYS—HEAT-TREATED.

Type.	Major Constituents. (Balance Al.)							Min. Mech. Properties.			Commercial Designation.
	Cu.	Mg.	Mn.	Ni.	Zn.	Si.	Fe.	U.T.S. Tons/sq. in.	0·1% P.S. Tons/sq. in.	Elongation % in 2 in.	
Solution treated (480° to 520° C.) and aged at room temperature											
Al/Mg/Si Plus Mn	—	Up to 1·25	Up to 1·0	—	—	Up to 1·25	—	16·0	10·0	20	Duralumin H.
Al/Cu/Mg Plus Mn.	4·0	0·6	0·6	—	—	—	—	25·0	15·0	15	Duralumin B 5.L.1
	4·0	1·3	0·9	—	—	—	—	28·0	17·5	15	Duralumin G D.T.D.270
Al/Cu/Ni/Mg	4·0	1·5	—	2·0	—	—	—	23·0	14·0	15	"Y" Alloy B.S.S.414
Solution treated (450° to 520° C.) and precipitation treated (120° to 175° C.)											
Al/Mg/Si Plus Mn	as above							20·0	16·0	10	Duralumin H.
Al/Cu/Ni/Mg Plus Fe, Si, Ti	2·0	0·8	—	1·3	—	0·6	1·2	27·0	21·0	10	RR.56 D.T.D.206
Al/Zn/Mg/Cu Plus Ni	2·2	3·0	—	Up to 1·0	5·0	—	—	33·0	27·0	8	RR.77

Trends of Development in the Aluminium Industry of Germany

By H. RÖHRIG, Chief of Research Department,
Vereinigte Aluminiumwerke A.-G.

Research and technological progress, as well as economic conditions, have broadened the field for aluminium in Germany. Consumption in recent years has grown at a more rapid rate than in other countries, and Germany is gradually assuming the role of pace-maker in the development and application of this metal which will assist development in other countries. The author discusses the organisation of the German aluminium industry, and reviews briefly the effect of research on progress in the application of the metal.

The true importance of any branch of industry may be assessed by examining the extent to which requirements are met by the products it places on the market, although full satisfaction of all requirements, whether they be new, or those that were already being satisfied by some prior product, cannot be given without very careful analysis, which takes into consideration not only the properties of the product itself, but also the requirements it is intended to meet.

Up to the present time, in no other economic sector have such exacting demands been made on aluminium as in Germany, nor in any other country have those responsible for the production and exploitation of this metal had to be so well prepared to meet such unexpected demands at short notice, both as regards the quality as well as the quantity of their products, and it was only by being able to reap the mature fruits of early seed, sown with such care on the fields of exploration, that they were in a position to cope with such demands. It may be assumed that these fruits were not gathered before they had ripened, inasmuch as it is quite plain that their enjoyment has not been marred by any unpleasant after-effects.

The growth in aluminium consumption that has taken place in Germany of late years is demonstrated by the following figures, which also provide a comparison with the total world consumption.

(The figures represent thousands of tons).*

Year:	1929	1930	1931	1932	1933.	1934.	1935.	1936.	1937.	1938.
Greater Germany (not including Sudeten area)..	33·3	28·6	24·5	19·5	28·6	52·9	87·4	104·7	132·9	175
The world (including Germany)	231	181	152	120·2	127·4	171·6	217·9	294·6	368·8	375

It will be seen from these figures that Germany's share has risen from 14·4% in 1929 to 31% in 1938.

It would be idle to characterise this development as being solely due to the measures taken in Germany to restrict the consumption of metals which can only be imported into that country at the expense of foreign currency; on the contrary, it is quite easy to adduce several arguments to support the contention that not until the last few years has Germany been able to catch up with progress made in a number of different fields of application in other countries, though, of course, in doing so she has been able to take advantage of considerable mature knowledge concerning the uses of light metals which was not available previously, as well as of the fact that development coincided with a material improvement in the economic situation generally.

These are general arguments which can be borne out by one or two actual examples. Thus, Germany was the only country that had to submit to restrictions in aviation, civil as well as military, for any length of time, there being no such limitation in any other country; even up to five years ago the percentage of high-tension cables made of

*Estimated from the Statistical Summaries of the *Metallges.*, 1938.

Armorial Bearings (Crests) by the sculptor Koelle (aluminium art casting).

copper was higher in Germany than in the U.S.A., in spite of the fact that this country has resources of raw materials far more prolific in the production of copper than of aluminium; aluminium was employed for architectural purposes at a much earlier date in England than in Germany, and the employment of this light white metal for making containers for preserved foodstuffs was begun and developed by Norway. If Germany is now assuming the role of pace-maker, she will, in turn, collect experience which will benefit and facilitate the introduction of aluminium in other countries.

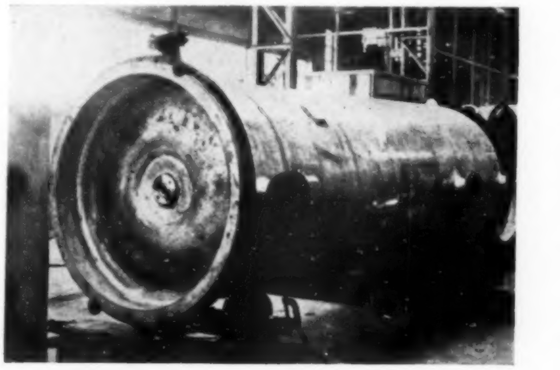
The laudatory idea of interchanging experience in the use of aluminium for civilian purposes is one that originated with the formation, more than 10 years ago, of the Bureau International des Applications de l'Aluminium, not the least of those to acknowledge the work of the Bureau being the actual users of aluminium themselves, and the activities of this body are also actively supported from the German side.

Horizontal Organisation

The German aluminium industry differs fundamentally from that of most other countries, inasmuch as in Germany only, an almost pronounced horizontal organisation has been retained; the actual aluminium producers have penetrated here far less into the working and finishing industries than in other countries. A factor that has contributed to this development has been the existence, for a considerable time past, of industries for semi-finished products, long before production on anything approaching an extensive scale was commenced. Prior to 1914 the only aluminium works in Germany was the Swiss-owned concern at Badisch Rheinfelden, whose yearly output of some 800 tons was wholly inadequate to supply the demands of the rolling mills and foundries operating in

Germany, amounting to some 10,000 tons; the deficiency was met by importing from England, France and Switzerland, and no change occurred in this state of affairs until war-time, when large aluminium factories were set up under strong influence brought to bear by the German Reich. The amalgamation of the factories controlled by the Reich subsequent to 1918 finally led to the formation of the Vereinigt Aluminiumwerke A.-G., whose various old and new alumina and aluminium electrolysis works now control by far the greater part of the total production.

As the producers of aluminium in Germany only supply the metal, and do not enter into competition with their customers, they have been able to build up an extensive advisory and propaganda service, aimed at promoting the use of aluminium. These activities were fostered by the research laboratories which producers had organised in the early days, and borne by an advisory organisation



Welded boiler end, Al 99.5%, 20 mm. plate thickness.

which was continually being expanded as the years went by. This advisory organisation is centralised in the Aluminium-Zentrale which has offices in Berlin, Düsseldorf and Stuttgart, and they issue the *Aluminium Gazette*, which has a circulation of 2,000 copes per month, also the aluminium pocket book, of which over 80,000 are distributed, as well as other publications.

Electricity Transmission Cables

One of the first realms on which research by the aluminium producers was concentrated, as in most other countries, was that of the manufacture of overhead cable systems, the first task undertaken being to ensure by an appropriate selection of materials that the wire strands should have the requisite resistance to corrosion and the desired conductivity. Another problem was to prevent the resistance of the wire to the effects of climatic conditions being adversely affected by scale or particles of base metal, such as copper, rolled into the wire, this risk being an ever-present one so long as both metals were worked up on the same rolls and through the same dies. The problem of combating cable vibration is one that was handled with particular care, and instructions for laying aluminium cables were drawn up specially, jointly with the actual users. Damping devices were also evolved, and in the end stranded-wire ropes were successfully produced which would, without any further measures, simply due to their structure, automatically damp the wire oscillations of the various frequencies to a minimum, by destroying the vibratory energy in so many points as to preclude any damage to the wires due to the beating effect. The fact that such confidence in aluminium overhead lines exists nowadays as to cause over 3,000 km. (approximately 1,875 miles) to have been put up since 1934, carrying voltages up to 100,000 and even more, is to the credit of the extensive pioneer work that has been carried out.

Taken altogether, the quantity of aluminium used in electrical engineering during the past year was equal to twice the total amount of metal produced in the year 1932. It may be assumed, however, that, but for the preliminary work accomplished, the conversions, speeded up by State regulations, would not have been carried out with equal smoothness.

Surface Protection

Another field of investigation where work has been intensified by co-operation between the laboratories maintained by the aluminium producers is the one relating to surface protection. An examination of the various principles covering the surface had been commenced at an early stage, and this had resulted in extensive knowledge being obtained in regard to the suitability of protective coatings for different purposes, the information being readily placed at the disposal of all interested parties. In addition, several processes have been developed for intensifying the protective effect of the natural film of oxide on aluminium itself, and in connection with this, mention should first be made of what is known as the M-B-V process. In this instance, effective intensification is actually obtained by a dipping process using an aqueous solution containing 1·5% sodium chromate with 5% of soda, the thickness of the coating deposited on the metal being twice 10^{-4}. A particular advantage of this cheap process is that the inaccessible internal surfaces of parts of apparatus such as coils of piping can be given a reliable protective coating very quickly merely by pumping the solution through them at a temperature of 98° C. (approximately 208° F.). During the last few years, moreover, it has been found possible to render this coating colourless by changing the composition of the solution in a suitable manner, this being an advantage that has been found very useful, especially in the case of things such as containers, bottle caps and similar articles used in connection with foodstuff packing. It is worthy of mention that this development was promoted through a prize competition organised by the Bureau International des Applications.

The second method which, by intensifying the film of oxide, could appreciably augment the possibilities for using aluminium and its alloys, is that of anodic oxidation. It may not be out of place to lay emphasis on the fact that the development of this process, which has since spread over the entire world, is as important a step forward as was the discovery of Duralumin in 1906 by the German investigator A. Wilm.

Protective films, as obtained by anodic oxidation, are considerably thicker, harder and more absorbent than those produced by the chemical (B-M-V) process; they are distinguished by high insulating properties, and so have opened the door for aluminium to the extensive field of electrical winding and coils; they are, furthermore, prominent by reason of their great resistance to weather conditions, their aesthetic appearance and their capability to absorb paints, water-repelling greases and photochemical compounds; the latter property forms the basis of the "Seo-Photo" process brought out by Siemens and Halske. The industrial uses of this anodic oxidation process for aluminium was applied in Germany with exceptional momentum, because the producers of the metal took an interest in it at an early stage and, by fruitful co-operation with the suppliers of the plant required for carrying out the process, they were able to promote its development and expansion by intensive research work. It is due to the activities of the Eloxal Operative Association that there are at the present time oxidising baths of more than 90,000 gallons aggregate capacity in operation in Germany. The quantity of aluminium treated by this anodic oxidation process—known in Germany as the "Eloxal Process"—is difficult to estimate, but at the present time it should amount to not far short of 10,000 metric tons. Some examples of the uses to which aluminium treated by the Eloxal process have been applied are shown in the accompanying illustrations.

From the very outset special attention has been given

in Germany to processes for improving the resistance of aluminium alloys to corrosion by plating them either with pure aluminium or with resistant alloys, the result being the practice has now reached such a high stage of perfection that the various demands made on the composition of the plated coatings can be met in every respect. One of the special products of this art is aluminium-plated copper, a product now known by the name of "Cupal."

Developments in Welding

A contribution, made by the research carried out by aluminium producers, to the field of jointing processes is the development of arc welding. When steel welding practice is considered, there can be no doubt that the employment of arc welding is bound to come more and more to the fore. As regards aluminium, experiences with autogenous welding have given satisfactory results for a number of years, but, with the more extensive adoption of aluminium, the requirements made on welding processes have increased considerably. It is desirable that the speed of welding should be increased. It frequently happens that parts of different metal thickness have to be joined, and with the increasing use of aluminium for engine construction it becomes more and more necessary to be able to carry out repair work by welding without warping the parts or causing any deformation of the fitted surfaces. For this particular kind of work the electric arc, with its welding heat concentrated in one spot, is an invaluable aid, provided that suitable electrodes to satisfy the welder's requirements are available. As experience during the last two years has shown, such an electrode has been produced in the shape of the Veral welding electrode (British Patent No. 485676), whose efficiency is based on a coating of special composition to suit its purpose, giving good solubility of the aluminium oxide and a melting point appropriate to that of the material to be welded. Different welding rods, varying from 2 mm. to 10 mm. in thickness, are supplied for various alloys. The accompanying illustrations shows a high-pressure boiler built up with the aid of these welding electrodes.

Improved Quality and Uniformity of Aluminium

The aluminium producers, in order to meet more exacting requirements as regards the quality and uniformity of the finished products, had to satisfy two different demands at once; they had continually to increase the purity of the crude aluminium, and they also had to keep on improving the quality of the rolling ingot. The first of these problems had to be solved in spite of an increase in production amounting to several times the original output, and the second demand had to be satisfied in spite of the weight and size of the rolled bars being continually on the increase.

Greater purity of the metal was desirable for two reasons: an increase in the silicon content is known to decrease the conductivity of the aluminium, as it is scarcely possible to get rid of these components altogether in hard-drawn wire. So as to comply with the greater demands on the conductivity of the metal, aluminium intended for the manufacture of conductor lines is being supplied by producers at the present time with a silicon content varying between 0·15% and 0·08%. The second admixture invariably present in aluminium is iron; a high percentage of iron adversely affects the resistance of aluminium and its alloys to corrosion, as well as being detrimental to the dissolving and separating processes in Al-Cu-Mg or Al-Mg-Si alloys amenable to refining by thermal treatment. The average purity of the aluminium placed on the market by producers nowadays is about 99·6% to 99·7%, though considerable quantities of still purer metal—up to 99·9%—are also made. This latter quality, is used, among other things, to an increasing extent for the manufacture of electrolytic condensers.

Where even greater purity of the metal is called for, electrolytically-refined aluminium is used. This exceptionally-pure metal, containing more than 99·99%

Shop panels made in anodial aluminium alloy.

of aluminium, is being produced in Germany by two different processes, the output being rather more than 100 tons per annum. Just as in other countries, aluminium of high purity has been adopted for a number of interesting uses; apart from electrolytic condensers, there is a great tendency to use it, or else alloys made up with it and some element like magnesium, for instance, for plating the Al-Cu-Mg alloys. The excellent ductility of pure aluminium, which is little less than that of lead, has also caused it to be adopted for various purposes which were closed to primary aluminium of ordinary purity: thus, sheathing for cables is now pressed from refined aluminium in the same way as lead, and as the thickness of the aluminium sheath can be less than that of lead, the weight of the sheathing is reduced to a far greater extent than the ratio of specific gravities of lead and aluminium (11·3 and 2·7, respectively).

The tendency to form coarse crystals in recrystallisation increases considerably as the purity of the aluminium improves, and if the formation of large crystals is to be prevented when working with pure aluminium, the working conditions which were satisfactory enough for aluminium of the standard of purity used hitherto must be altered.

New research work in this field was indispensable, and the methods employed for determining the impurities in aluminium in analytical laboratories also have to be revised, as it becomes necessary to determine percentages to thousandth parts, and not to tenth parts only, of one per cent., as previously. Calometrical analysis has produced good results in this connection, in place of gravimetrical analysis, but even this method has only been developed after much painstaking preliminary work.

Fresh impetus has been given to research work in connection with the constitution of aluminium alloys by the production of aluminium that is now practically free from the usual impurities such as silicon and iron, and particularly valuable work has been carried out, *inter alia*, at the Kaiser Wilhelm Institute for Metallurgy, at Stuttgart (Professor Dr. Koester), and the Technical High School, in Berlin (Professor Dr. Hanemann).

Alloy Developments

Remarkable developments have taken place in Germany in the field of the production of alloys since the expiry of the Duralumin patent. For many purposes, the high strength values of tempering Al-Cu-Mg alloys are not necessary, easier working properties and greater resistance to corrosion being required in many instances; aluminium alloys which satisfy these requirements are those which, in addition to magnesium, contain small quantities of silicon in a proportion which renders possible the formation of the Mg_2Si compound, which is soluble in the basic metal. The tensile resistance of sheets and sections made of this alloy is, according to the thermic improvement, 75% to 80% of that of Duralumin. As the resistance to

corrosion of these alloys, free from copper, is considerably higher than that of Duralumin, it may be assumed that the mechanical strength properties are retained, even under very stringent corrosive conditions.

This alloy, therefore, proved invaluable in many cases where constructional parts have to withstand the effects of sea water. The alloys which were first placed on the market under the name of "Pantal," are particularly favoured for making forgings, as they are distinguished by their great malleability.

In purposeful deviation from the principle of tempering, the development of alloys which contain aluminium, and chiefly magnesium only, has now been perfected. Such alloys were first of all brought out by the I.G. Farbenindustrie at Bitterfeld, under the name of "Hydronalium." The strength values are equal to those of Duralumin, but actually are obtained solely by a kneading process and without resorting to any thermic improvement. When these alloys are heated, as there is no temper effect, only relatively slight loss of strength occurs, and this property renders the Al-Mg alloys particularly suitable for constructional purposes where welding has to be undertaken. Apart from this, these alloys are distinguished by their resistance to corrosion, provided their structure is homogeneous or possesses a certain heterogeneous texture, and this resistance to corrosion makes them suitable for structures subject to severe corrosive attack. Provided the magnesium content does not exceed 3% to 5%, the alloys are comparatively ductile; in addition, they are particularly suitable for parts on which oxide films are to be produced (anodic oxidation) to give aesthetic effects.

In an endeavour to obtain thicker oxide coats by means of the anodic oxidation process, so as to permit of good appearance and greater variations in the shades of colouring on alloy castings, alloys have been evolved during recent years containing the combination $MgZu_2$ as the improving component. In the tempered state, such alloy castings reach resistance values of 40 kg./sq. mm., and a particular advantage of this type of alloy is its suitability for anodic oxidation in addition to its resistance to corrosion. Apart from its use for fittings for doors and windows and similar parts, this alloy has also been used to a considerable extent for casting plastics and type for printing.

Progress in Application

The fundamental characteristics of the development of the aluminium industry in Germany, in addition to the expansion of production, is the progress this light metal has made in a number of different fields, such as:

1. Architecture and art casting.
2. Vehicle construction, including shipbuilding.
3. The construction of apparatus for the chemical and foodstuffs industries.
4. The packing industry.

In all these applications aluminium has had to satisfy demands that are considerably more exacting than in previous decades as regards resistance, chemical stability and aesthetic appearance, and if it has been possible to open up all these fields to aluminium, then the early preparatory work carried out and the work of research into the manifold properties of aluminium have indeed rendered good service.

One of the most important factors which would seem to justify the expectation that aluminium will continue to hold the positions it has won may be seen in the fact that many thousands of metal workers and craftsmen have become familiar with handling the metal, and that a generation of designers has grown up which is accustomed to plan in light metal.

Aluminium and the Swiss National Exhibition

At the last Swiss National Exhibition, held in Berne in 1914, aluminium was included in the general range of materials used in the engineering industry; at the forthcoming Exhibition, to be held in Zurich from May 6 to October 29, the whole producing and manufacturing aluminium industry will be represented. A special building, with a floor area of about 2,510 sq. yds., is allocated to the display of aluminium products, which present as complete a demonstration as possible of the Swiss aluminium producing and manufacturing industry. The visitor will be able to follow the most important operations presented. In order to illustrate various operations in the working of aluminium and its alloys, instructive films will show method employed in casting, welding, riveting, forging, surface treatment, and will also include investigation methods. It is proposed to present short lectures when these films are shown, in order that they will have real educational value.

As the manufacture and application of aluminium in its many forms has rarely been exhibited on such a large scale as that planned for the Swiss National Exhibition, it is to be expected that those associated with the development and application of aluminium in other countries will interest themselves keenly in this Exhibition. The light metal expert will be especially interested in the arrangements made to hold an aluminium congress on September 12 and 13 at the Federal Technical University, Zurich, at which Professor Dr. A. Rohn, Chairman of the Swiss Board of Education will officiate. Famous light metal specialists of world-wide reputation have promised to contribute to this Congress.

This Aluminium Congress is intended to complete the Light Metal Display at the Swiss National Exhibition, and all light metal experts who can make suitable arrangements are recommended to fix their visit to the National Exhibition for the period towards the middle of September. This would enable them to attend the Congress. A detailed programme will be announced later on.

Developments in the Production of Extruded Sections

The installation of new plant for the Northern Aluminium Company will enable larger extruded sections to be produced, a factor that will be of particular importance in all forms of structural work. The larger sections that will become available will eliminate the need for building up from composite parts, whilst the single extrusion logically represents an increase in the ratio of strength to weight. Further, this will mean, in such applications, a reduction in labour and handling charges. The company has found that there is a rapidly increasing demand for these larger extruded sections for structural work, and the wider ranges now available should be of definite significance in regard to the further application of aluminium in constructional work.

650 U.S. Planes Ordered

The Air Ministry has increased its order of United States aeroplanes. The official announcement stated that in view of improved deliveries in prospect under the orders for aircraft placed by the Air Ministry in the U.S. last year, it has been possible to negotiate an increase in the contracts for delivery within the period originally contemplated. The order for Lockheed General Reconnaissance (Hudson) aircraft has been increased from 200 to 250 and that for the North American Trainer (Harvard) from 200 to 400.

Arrangements were completed in June last year for 400 American planes, and it was expected that they would be ready for delivery to this country within a year of that time.

The Manufacture of Aluminium Alloy Forgings and Stampings

By J. Towns Robinson

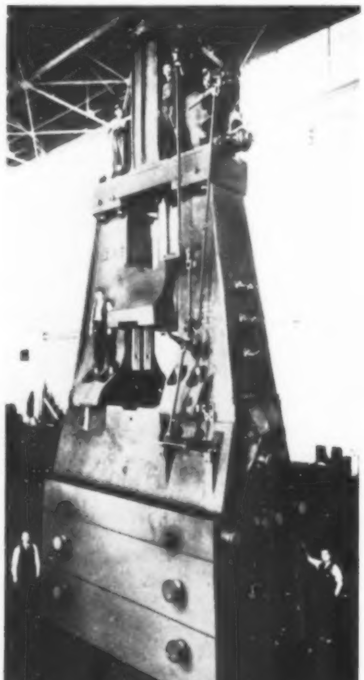
Technical Superintendent, High Duty Alloys Ltd.

Parallel with the development of high strength aluminium alloys has been the progress in manufacturing technique. Rolling, extrusion, forging and stamping of these alloys has rapidly advanced. Soundness and good physical properties are no longer sufficient for forgings or stampings; questions of grain flow and strength in preferential directions, internal stress and suitable heat-treatment also arise and in this article is briefly outlined the fundamental procedure and principles of the working of wrought alloys.

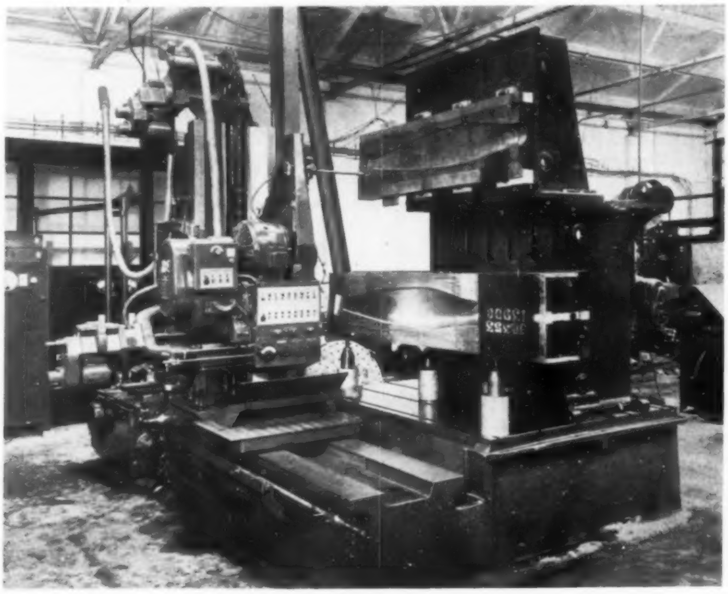
THE working of aluminium alloys such as forging, stamping, extrusion and rolling, has made an enormous advance in a comparatively short time, and the technique has now reached a remarkably high standard. The rapid development of the aero engine and the demand for lightness combined with high strength, opened up an entirely new sphere for the use of wrought aluminium alloys. The urgency of this demand did not allow of extensive research in a national sense, therefore, the manufacturer was compelled to speedily develop his own working technique, and confine the results of his own individual research to methods of production. These circumstances therefore, naturally resulted in the working of aluminium alloys becoming of a highly specialised nature. This is of course also true due to the inherent difference, both in the working and characteristics, between aluminium alloys and steel, and it is important to remember that this difference is really very wide.

The increased power ratio and performance of modern aircraft has made it more imperative that a forging or a stamping must of necessity have properties which were practically unknown only a comparatively short time ago in the same type of component. Soundness and good physical properties alone are no longer sufficient, and the questions of grain flow and strength in preferential directions, internal stress, and suitable heat-treatment have had to be answered. For instance, such important parts as pistons, cylinder heads, cylinder barrels and supercharger rotors, apart from possessing a fine crystal structure, must have maximum strength in all directions, combined with a suitable ductility, which can only be achieved by the adoption of a special forging or working technique applicable to the requirements of the individual part.

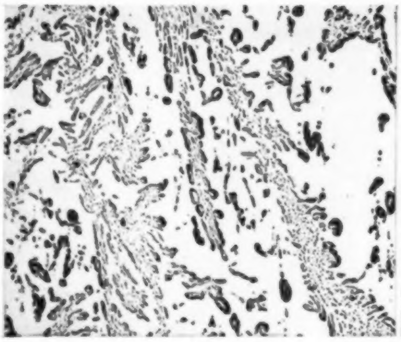
The present-day standard of these requirements is so high that a much greater degree of work or manipulation and control of the working processes is necessary than was hitherto required. The study of crystal or "lattice" structure by means of crystal X-ray has played probably the most important part in the scientific research appertaining to this development. Improvement in modern working plant both in regard to furnaces for heating, and larger and heavier forging equipment has also made

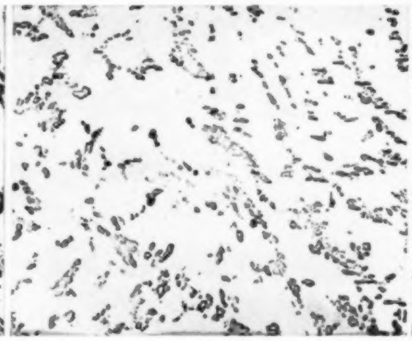


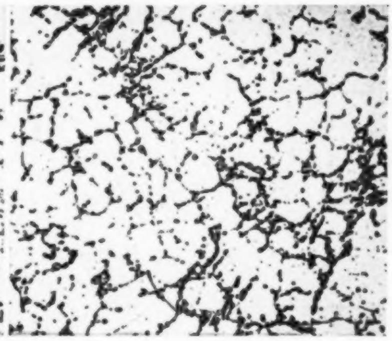
A typical example of the power plant required and the production of aluminium alloys is seen in the illustration of the Erie Drop Hammer which Messrs. High Duty Alloys are installing at their Redditch factory, and will be employed on the stamping of aero engine crankcases and airscrew blades. This hammer has a total weight of 470 tons, of which the anvil accounts for 360 tons. The total weight of the falling parts including tup, die, piston and rod, is 29 tons.



Automatic "Keller" die-sinking machine showing half die for propeller blades.







Specimen of Hiduminium RR 56, showing coarse areas of eutectic indicating incomplete breakdown during working. × 100. (Reduced on reproduction.)

Specimen taken from a supercharger rotor stamping in Hiduminium RR 56, showing uniform crystal structure. × 100. (Reduced on reproduction.)

Specimen taken from a Hiduminium RR 59, stamped piston showing uniform and well distributed crystal structure. × 100. (Reduced on reproduction.)

immense strides, and resulted in greater control and efficiency.

Steel, for instance, is fairly malleable and flows comparatively easy, aluminium alloys, however, due to their complexity of constitution, do not flow easily, and, what is no doubt surprising to the uninitiated, require a very much heavier blow than does steel, and are in consequence much more severe on die life. Deformation, either by hammer blows or pressing, must be such so as to penetrate to the interior of the working "stock" employed, otherwise surface deformation only would result, and the unworked interior would give rise to either internal cracking or breakdown, or inequalities in the properties of the finished part.

The quality of the original cast ingot is of paramount importance, whether it be for the production of forgings or extrusions. It must possess a fine even crystal grain size and structure, free from porosity, segregation of constituents, non-metallic inclusions, etc. This is by no means a simple matter when one considers the large size of ingots which are necessary for the production of the larger type of stampings employed in present day practice. The complex constitution of aluminium alloys and the formation of its intermetallic compounds calls for a high degree of foundry or casting technique in the production of large ingots. If segregation or coarse agglomeration of constituents exist in the cast ingot, no amount of working or breakdown will produce a sound stamping, and the finished part is bound to suffer from a multitude of troubles. A strict and rigid inspection of the stock material prior to working, whether it be cast ingot or extrusion, is absolutely necessary to ensure sound material and it is good policy not to allow any material with the slightest of defects to proceed to the forge shop.

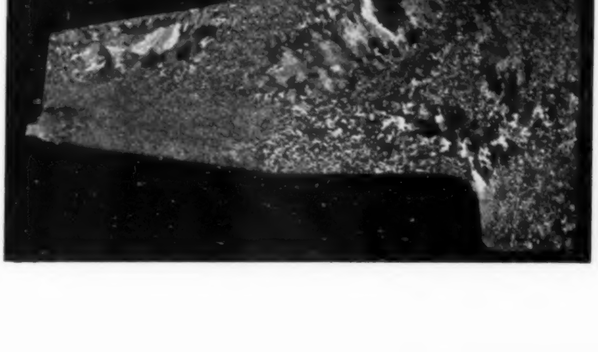
Working stock for forging can be divided into three categories, viz., cast ingots, extrusions and rolled bars, and each has its own particular purpose and the nature or design of the final stamping really decides which can be used to the greatest advantage. For example, propeller blades and connecting rods in which the service stresses are mainly in the longitudinal direction, a preferential grain flow is desirable and here extruded or rolled stock can conveniently be used with advantage. If cast ingot is used for large and bulky stampings, a very considerable amount of work or breakdown is necessary to transform the coarse crystalline cast structure into a fibrous structure.

Large cast ingots are usually broken down in the first stages by pressing, which consists of applying the work or deformation in all directions, that is, on all planes of the ingot. Very considerable pressures are required for this operation as instanced by the 3,000-ton capacity press seen in the illustration. After pressing the wrought stock is subjected to further breakdown either by hammer forging or taper swaging, by means of tapered tools in preparation for the final dummy stage.

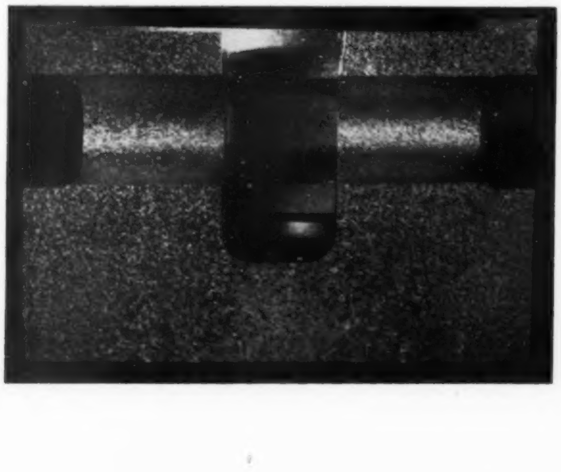
If cast ingots are broken down under the forging hammer, very light blows must be given at the commencement to transform the cast structure at the surface. If the blows are too severe, surface cracking will take place, and in most cases complete fracture of the ingot. It must be remembered that aluminium alloys do not weld up under the forging process, therefore, any cracks or fibre rupture which takes place will simply result in either surface or internal defects upon further forging. It is imperative therefore, that when surface cracking occurs, the cracks or other defects must be immediately removed, either by chipping out or hand milling before further work is imparted.

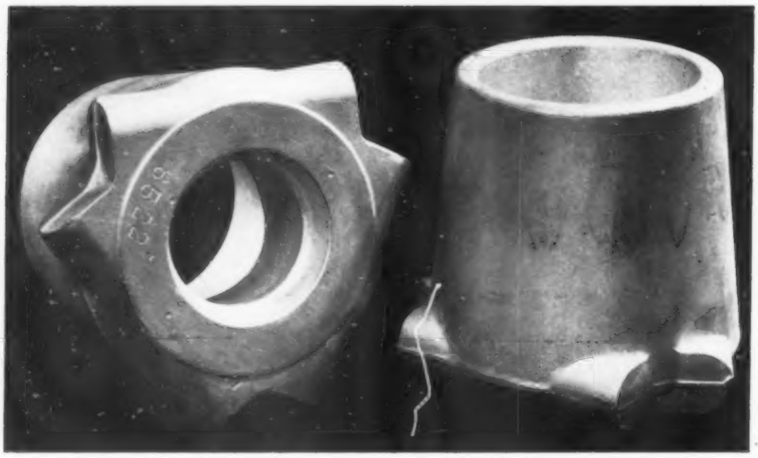
Forged bar stock prepared by hammer forging should

Macro-structure of a Hiduminium RR 56 supercharger rotor stamping showing marked difference in crystal orientation and lack of uniformity.



Macro-structure of Hiduminium RR 59, forged piston made as a plain cheese type forging, showing the lack of defined grain flow due to the manner of production.





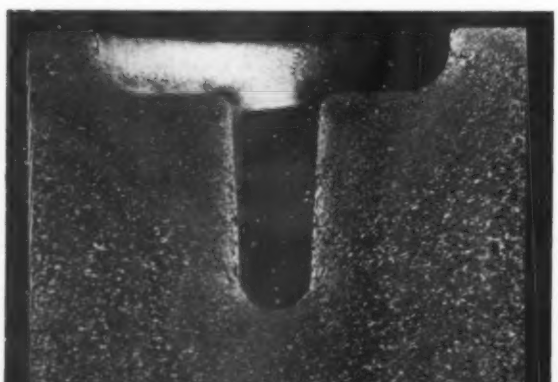
Hydraulic cylinder stampings in Hiduminium RR 56.

be pickled in an acid bath, and the surface thoroughly inspected, and any small cracks or surface defects removed by hand milling before proceeding to work up into dummy form.

When using cast ingot the finer the constituent particle size and uniform distribution, or, in other words, the micro structure of the original ingot, the more homogeneous will be the final stamping, providing that adequate and sufficient work has been imparted. On the other hand, no amount of working or forging will thoroughly transform or break up an extremely coarse original cast crystal structure. When breakdown has been carried out under the press on the cast ingot it must be borne in mind that the work or deformation has occurred on all planes resulting in complete break-up of the hard constituent particles which are not subject to plastic deformation in the soft matrix, its aim being the production of homogeneous material. It is necessary therefore, to impart further work by drawing out under the hammer or swaging tools, to produce preferential grain flow if this is desired in the final stages. Likewise, when using extruded stock in which the grain flow is in the longitudinal direction, upsetting under the forging hammer is necessary to break up and re-distribute the preferred grain orientation and produce homogeneity in all directions. The use of extrusions for forgings and stampings enables alloys which are practically unworkable in the cast condition to be fairly readily forged and stamped.

The heating of the stock for forging is a very important part of the process of working, and particularly so when cast ingots are used. Uniformity of temperature control is the first stage, as irregular heating will lead to endless troubles which will be reflected in the quality of the finished part. Heating can be done by the molten salt bath, gas-fired or electric furnace. The salt bath method is only employed for forging work or break-down under the hammer, and cannot be used for the stamping process owing to the effects of the salts on the surface of the dies.

Macro-structure of a Hiduminium RR 59 die-stamped piston showing uniform crystal size and grain flow.



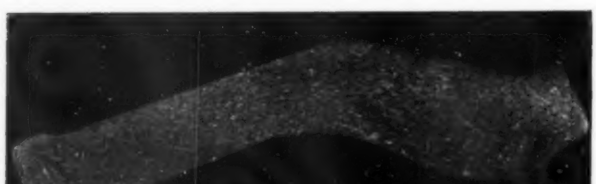
In the past, considerable trouble has been experienced with air-furnaces owing to the difficulty of obtaining efficient temperature control to fairly narrow limits on the lower range of temperatures employed on aluminium alloys. My Company has carried out a considerable amount of research, both on the economic working and efficient temperature control, which has proved very successful and resulted in the construction of our own furnaces. The time and regulation of heating must be so controlled as to thoroughly and uniformily heat the working stock completely throughout its bulk. When using cast ingots, a pre-heating or solution treatment extending up to 20 hours and even longer at a temperature of 480° to 500° C. is necessary to take into solution the alloying constituents, to facilitate working and obtain uniformity of material. This treatment is, of course, not necessary when using extruded stock in which breakdown of the original cast structure has already taken place.

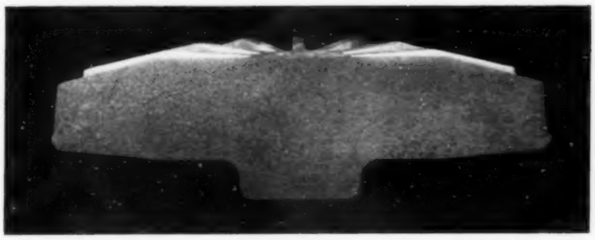
The effects of un-uniform or overheating are not always manufest until the heat treatment stage or even the final testing for mechanical properties is reached, and hence a considerable amount of scrap can arise. Temperature control of the actual furnace, however accurate, is not sufficient alone and it is necessary to check the temperature of the ingots or billets by means of a suitable contact pyrometer, both before and after each operation. This should be a systematic routine, and the temperature at the finish of the operation is most important, as the final mechanical properties depend to a large extent on the amount of deformation at critical temperatures.

The shape and volume of the dummy prior to stamping, should be standardised after these features have been established by the first trials. The dummy should conform as near as possible to the contour of the die, and should be so designed to produce the minimum of flash, as excessive blows from the hammer will only cause fibre shear through the flash line.

In cases of stampings of intricate design or irregular shape, the use of preparatory dies are essential before finally stamping to size. As in the case of forged stock any surface cracking or skin folding must be removed immediately these defects occur, otherwise a high percentage of scrap on the finished parts will result. A rigid inspection of all dummies both for size and surface defects previous to stamping should be instituted and any defects removed by milling. The weight of the hammer employed during stamping is governed by the size and design of the

Macro-structure of section of aero-engine gear case stamping in Hiduminium RR 56.





Half section of Hiduminium RR56 supercharger rotor stamping. Macro structure shows fine, uniform crystal grain size and flow.

individual stamping and is naturally only determined by practical experience. As already stated, aluminium alloys do not flow readily, and proper care and attention must be exercised both to assist the flow of the material and to produce the grain flow best suited to resist the working stresses imposed in service.

This necessitates intelligent thought in the design of the die to ensure an uninterrupted flow of the material throughout the die. Plastic deformation is fairly rapid when the flow is uninterrupted, but when the material is filling the die, the flow becomes more difficult, and a considerable number of blows are required to produce the finished stamping to size. If the geometrical shape of the dummy is such as to create excessive pressure in any particular part and offer resistance to flow, exaggerated crystal orientation will take place which can result in bands or areas alternating between very large and very small crystals, destroying the continuity of crystal grain, with dangers of cleavage weakness between the crystal planes and hence effecting the physical properties.

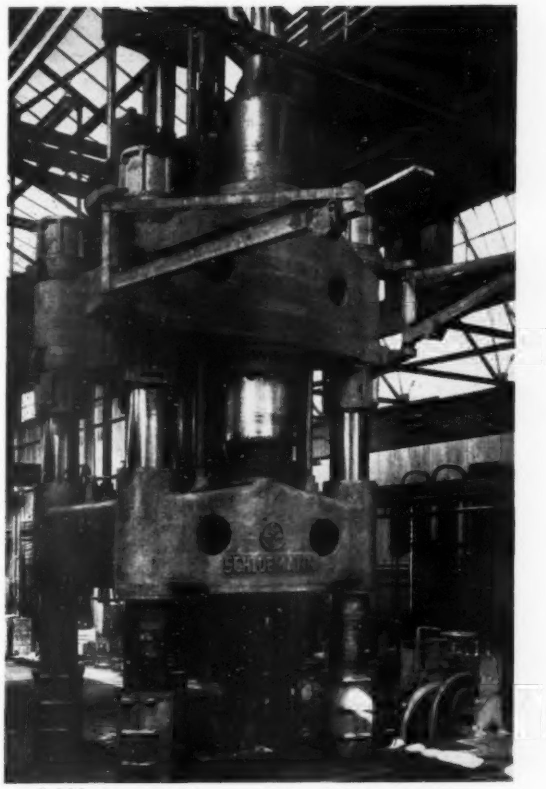
The design of stampings as instanced by supercharger rotors in which the vanes are stamped and pistons with a honey-combed network of ribs on the inside of the crown, have become increasingly more difficult, and call for an exceedingly highly developed forging technique. These parts, in company with many others such as aero engine cylinder barrels, require the combined process of both the drop hammer and the press for their production.

Large stampings such as crank cases, etc., which are usually produced from cast ingot, involve a considerable number of working operations and processes before stamping and each of these must be carefully thought out and controlled to fulfill a definite purpose relative to the manner of breakdown, uniformity and direction of grain flow, and limits of temperature to produce satisfactory physical properties. After the stamping operation the parts should be acid pickled and inspected before being finally heat-treated, as by this means any surface defects can be detected: this can also be of great assistance to the stampers in ascertaining if any surface or skin folding has taken place.

Aluminium alloys, due to their resistance to deformation, are extremely severe on the steel stamping dies, and many difficult problems have arisen and have had to be overcome as a result. The direction of grain flow in the manufacture of the steel die in relation to the sunken impression is also of the utmost importance. The best steel for stamping dies has been found to be the nickel-chrome-molybdenum steel, heat-treated to give an approximate Brinell hardness of about 300.

The purpose of this article has been to outline briefly the fundamental procedure and principles of the working of wrought alloys, and an explanation of the highly scientific technique involved has not been attempted. It is hoped to deal with these features also the heat treatment of the wrought alloys at a later stage. There is a very wide difference in the workability of the various alloys, and the "Hiduminium" alloys have been so designed to give ease and freedom of workability as one of their many salient features.

As stated at the beginning, the forging of aluminium alloys has developed into a highly specialised technique



3,000-ton capacity press for hot breakdown.

and naturally as such each and every stage must be scientifically controlled and understood to produce successful results. It must also be borne in mind that the working temperatures are very low as compared, for instance, with steel, and the temperature ranges very narrow which of itself necessitates the strictest of scientific control.

The United States Bauxite Industry in 1938

The recession in industrial activity during 1938 was reflected in the domestic bauxite industry by declining shipments of domestic and foreign bauxite to consuming industries, according to preliminary annual figures.* Shipments from mines in the United States in 1938 totalled only 319,000 long tons, valued at $1,838,000, a decrease of 24% in quantity and 25% in value, compared with 1937. All of the decrease was accounted for by mines in Arkansas and Georgia, shipments from Alabama having increased. The average value per ton of all domestic shipments declined from $5·82 per ton in 1937 to $5·76 in 1938.

During the first eleven months of 1938 bauxite imports decreased 8%, compared with the corresponding 1937 period, and exports of bauxite and bauxite concentrates decreased 53%, compared with the same period of 1937. Receipts from Surinam advanced 2% over those of 1937, while imports from British Guiana declined 31%. Surinam accounted for 85% of the total imports from January to November, inclusive, 1938, as compared with 77% in 1937, whereas the percentages from British Guiana were 13 and 18 respectively. The balance of the bauxite (2%) came from Greece and Netherland India in 1938.

Of the eleven months exports in 1938, 40,358 tons were bauxite and other aluminium ores, and 13,925 tons consisted of bauxite concentrates (alumina, etc.). The respective tonnages for the corresponding period in 1937 were 76,539 and 37,823. In 1938 Canada again took all of the cruder materials and 3,884 tons of the bauxite concentrates (alumina, etc.). Of the other bauxite concentrates, 8,966 tons went to Norway, 1,073 to Sweden, and the balance to Denmark, China, Brazil, and France.

* Issued by the Bureau of Mines, United States Department of the Interior.

Proved Applications of a Corrosion-Resisting Light Alloy

By G. O. Taylor

Most commercial aluminium alloys, because of their film-forming characteristics, are properly regarded as corrosion resistant, but since the term is purely relative some alloys resist most corrosive conditions better than others do ; thus among the aluminium alloys are several that have been specially developed for application under such conditions. One of the pioneer alloys of this type is discussed and some of its applications described.

CONCURRENT with the rapid developments in the production and application of the light alloys of aluminium within the last few years, many new materials are being marketed with claims for the combination of high tensile strength and resistance to corrosion.

It must be borne in mind, however, that much of the success in the application of corrosion-resisting strong light alloys, depends not only on the passing of tests under laboratory conditions, but also on an intimate knowledge of the relation of laboratory tests to service conditions. To acquire this knowledge in relation to such specialised materials as corrosion-resisting light alloys, demands a close observation of the behaviour of the material, under various practical conditions, over a number of years.

A typical application of polished Birmabright for the framing of cockpit covers and cabin windows.

It is now conceded that the best of the corrosion-resisting aluminium alloys, are those that contain as the alloying element a few per cent. of magnesium with or without the addition of a small amount, usually under 1%, of manganese. Several alloys of this type have been marketed within the last eight years, but the pioneer and most widely applied alloy in this range is " Birmabright," which by virtue of its seniority in the field of practical application has now become a material of considerable importance.

This light metal, which is a patented alloy, contains 3·5% of magnesium with 0·5% of manganese. Other alloys are available, with both higher and lower magnesium contents and higher and lower mechanical properties, but the pioneer material has proved in practice to be the happy medium from the users' point of view.

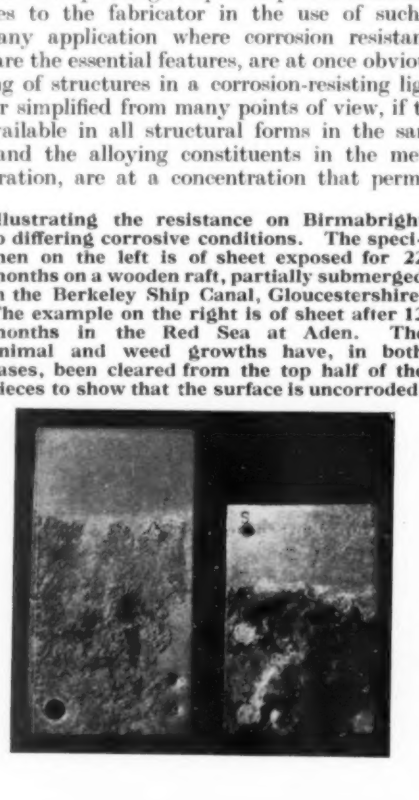
It is a fact of great importance to the fabricator that the high tensile strength of the alloy is derived solely from cold working. It is not, therefore, necessary, as in the case of certain other types of strong light alloys, to subject the completed work to heat treatment, with its attendant complications of expensive plant and production hold-up.

When it is appreciated that in certain wrought forms the tensile strength of " Birmabright " can be as high as 25 tons per sq. inch, with a reasonable per cent. of elongation, and that in the hard, medium, or soft conditions the strength is approximately two and a half times greater than that of the corresponding tempers in pure aluminium ; the advantages to the fabricator in the use of such a material for any application where corrosion resistance plus strength are the essential features, are at once obvious.

The planning of structures in a corrosion-resisting light alloy is further simplified from many points of view, if the material is available in all structural forms in the same composition, and the alloying constituents in the metal under consideration, are at a concentration that permits

Part of an order for 30-ft. lifeboats, constructed entirely of Birmabright, to Board of Trade requirements, for the Union Steamship Co., of New Zealand. The weight of a fully equipped boat is 2 tons 16 cwt. which is approximately 1 ton 7 cwt. lighter than similar boats of wood or steel construction.

Illustrating the resistance on Birmabright to differing corrosive conditions. The specimen on the left is of sheet exposed for 22 months on a wooden raft, partially submerged in the Berkeley Ship Canal, Gloucestershire. The example on the right is of sheet after 12 months in the Red Sea at Aden. The animal and weed growths have, in both cases, been cleared from the top half of the pieces to show that the surface is uncorroded.



this desirable property to be achieved. As will be seen from the accompanying illustrations, this alloy can be produced in a variety of forms that it would seem almost impossible to achieve without variations in composition to introduce special properties that may be desirable in one or another of the manufacturing operations.

Without the slightest change in composition, the metal can be produced as sand, gravity, or pressure die-castings, rolled sheets, tubes, extruded and drawn sections, spinnings, deep drawings, hot stampings and forgings, wood and metal thread-screws, rivets, wire, gauze, and it is suitable for the operation of drawing upon wood. It is this remarkable versatility of form into which the material may easily be manipulated that has rendered possible the outstanding structural achievements now reviewed.

In the sphere of marine architecture, " Birmabright " is long past the experimental stage and is a proved and accepted material, with a large and rapidly growing list of achievements that cannot be claimed for any other light alloy.

During the development of this alloy it was subjected not only to long and rigorous tests in the laboratory in comparison with many other types of light alloys, but also to actual field tests in many parts of the world. These comprised exposure, for as long as two years, to conditions as widely differing as those obtaining in a river in Gloucestershire, to 20 ft. down in Plymouth Sound, from conditions in the Red Sea at Aden, to those in Hong Kong and the Malay States, from a lake in South America to a lake in Central Africa and in many other places, in all cases with successful reports. Specimens from such actual field tests are illustrated and the remarkable freedom from corrosive action can be observed on the portions of metal cleaned after the test.

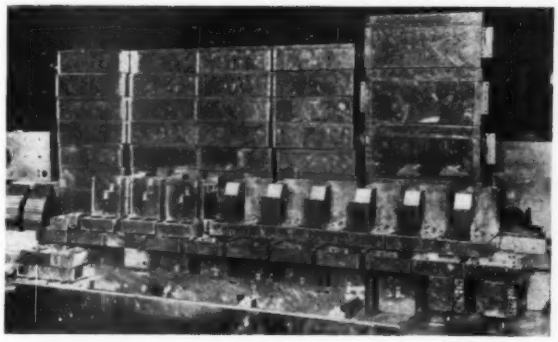
The proof of this patient and exhaustive testing culminated in the building and successful use of the all-" Birmabright " boat. After the service testing of small craft up to 22 ft. in length, a large motor cruiser *Diana II*, 55 ft. long, was ordered in the same material. This particular vessel, which was at the time, the largest all-light-alloy craft afloat, has now been in use in both home and Mediterranean waters for seven years and the latest report by the owner a few weeks ago was that it was in excellent condition and showing no signs of deterioration.

This vessel, which represented a considerable development in the applications of light alloys, was shortly afterwards eclipsed in size by a 20-knot, 65-ft. patrol cruiser, built for the Royal Canadian Mounted Police. This remains the largest all-light-alloy boat in the world and is in active service.

It is of particular interest that this vessel was built throughout in a Canadian shipyard, solely by Canadian labour unskilled in the manipulation of aluminium alloys, and also without personal supervision by anyone who had handled " Brimabright " before. There can be no more fitting tribute to the ease with which fabrication in the metal can be carried out than that an achievement of this nature could be accomplished under such conditions.

Now there are close on 200 craft of all types and sizes in active service in all parts of the world, and a new page in marine history has been turned by the adoption of the all-" Birmabright " lifeboat by several large shipping companies for new ships recently built, and in building. In the course of the four years that have elapsed since the building of the first lifeboat, (which incidentally is now well-known to the marine world as " Barnacle Bill "), 85 lifeboats have been built or are in building.

It is again of interest to fabricators and potential users of light alloys that the proved reliability and facility of manipulation of this light metal are reflected by the fact that such vital structures as lifeboats can be built in various shipyards in different countries, again without personal supervision by the suppliers of the material, simply by following the few printed instructions and observing the few elementary fundamentals of construction issued with the metal.



The ease with which fabrication is carried out is shown by this illustration of a group of battery boxes and chassis for mobile radio equipment.

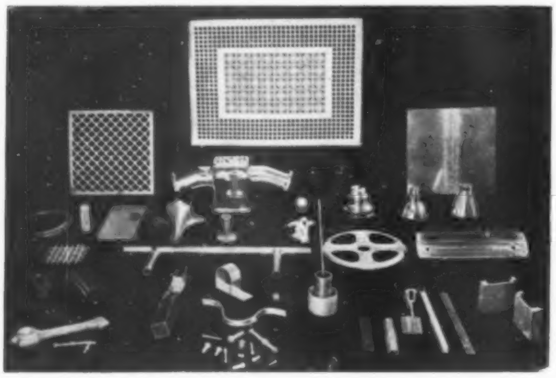
The facility with which " Birmabright " can be cast has led to its adoption for many types of boat and yacht fittings, for ships' sidelights, for parts of both large and small marine engines, for cabin fittings and for many other minor applications where the need is for a metal which is not only resistant to seawater but sufficiently strong to replace brass or gunmetal parts, with but little modification to pattern design, and without the necessity for heat treatment.

In the aircraft industry where full advantage can be taken of its light weight, strength and resistance to corrosion, " Birmabright " is extensively used. It is being generally recognised that where manufacturers are unnecessarily using heat-treated alloys for medium-stressed parts, the metal can be substituted with great advantage for engine cowlings, fuselage and wing coverings, seaplane floats, flying-boat hulls, cockpit and gun-turret frameworks, tubular seats, wheel spats, radiators, oil and hydraulic service pipes and other parts. Air Ministry Material Specifications D.T.D. 165, 170A, 175A, 180A, 209A, 249, 266 and 310, cover the metal in its various forms.

On land, the high resistance of the alloy to atmospheric corrosion has enabled it to be used with considerable success as an architectural metal, and in this sphere particularly, the ease of manipulation into the intricate shapes often necessary, is of great appeal to the craftsman in decorative work.

Again the remarkable versatility of form is of advantage, in that it is possible to build up a structure from both wrought and cast forms, with the assurance that under weathering conditions all of the parts will behave in the same manner and will not exhibit variations in colour. In any application where anodising is the specified finish, the advantages of uniformity of chemical composition of the various parts is an almost essential feature, and fortunately " Birmabright " is an ideal metal from the point of view of analysis for treatment by any of the known anodic oxidation processes. Also of importance in this field is the facility with which the metal can be given a mirror polish without departure from the ordinary technique, and the ease with which the polish, once given, can be preserved.

For general industrial purposes the uses of the metal are many. The freedom of the alloy from heavy metal additions renders it a very suitable material for the handling of foodstuffs, and it is without toxic effect. In this field, the immunity of the metal to the action of lactic acid and its consequent freedom from deleterious action on milk, has led to a very successful use for parts of automatic milking machines, for milk bar pumps, milk containers and similar applications. For the handling of fish it is especially suitable, and it has also found application for butchers' fittings for use with refrigerated meat where sulphur-dioxide is used as a preservative.



A group of products in Birmabright illustrating the facility of fabrication. Shown in the photograph are sand and gravity die-castings, spinnings, pressings, wire work, hot forgings, tubing, extruded and drawn sections, welded sheet, sections drawn on wood, and nuts, bolts and rivets.

The excellent resistance of the alloy to the action of hard water has enabled it to find application for swimming-bath hand rails and fittings, pump and radiator parts of automobile engines, cooling coils, and for rotary crystallisers where cooling is effected by water sprayed on the outside of the drum.

In the chemical engineering field, it is of interest that "Birmabright" is not affected by boiling glacial acetic acid or acetic anhydride, even after prolonged use, neither does it cause discolouration of the acid. It has, therefore, been used for such fittings as cocks, valves, level-gauges, man-hole covers, tanks, etc., with excellent service records. Similarly, since the metal is not affected by turpentine, linseed oil, etc., and has no deleterious action on their colour, it has been used for varnish plant.

It is, of course, possible to review many other uses, but the brief survey given should afford an indication of the types of applications where this aluminium alloy can be used with advantage. It cannot, however, be too strongly emphasised that much of the success in the application of this alloy in its many fields has been due largely to the fact that it is a material simple to manipulate.

In conclusion, therefore, it will not be out of place to describe briefly a few of the methods employed :—

Forming.—The forming of sheet is carried out in a manner similar to that adopted for pure aluminium. Only in cases where forming is very severe and the cold-working effect therefore pronounced, is it necessary to resort to annealing, which is carried out in situ by playing a blow-pipe flame on the area it is desired to soften for further working until a match stick rubbed on the metal just begins to char.

Riveting.—"Birmabright" rivets do not require to be softened and can be closed cold as received. They are very tough and not liable to the shortness after heading which is one of the disadvantages of rivets of the heat-treated type. When closed the tensile strength of the rivets is 20 to 22 tons per square inch.

Bending and Forging.—Tubes and extrusions can be bent and/or forged in a normal manner. Local annealing with a blowlamp is all that is necessary to counter cold-working effects.

Welding.—Autogenous welding presents no difficulties and is carried out with a welding stick of the same chemical composition as the parts to be joined. The blowpipe nozzle is of the same size or a size smaller than that used for mild steel of a similar thickness and oxygen is reduced to the minimum. Welded and hammered seams in sheet will offer practically the same strength as the sheet itself after cold-hammering, while welded cast pieces are actually stronger at the weld. A welded seam is equally as corrosion resistant as the rest of the structure.

This facility of welding is an important advantage of "Birmabright" over certain other alloys deriving their strength from heat-treatment.

A hotel fascia in anodised Birmabright and black glass.

Soldering.—Joints can be made by soldering with any of the proprietary solders marketed for the jointing of aluminium alloys. Soldered joints are not, however, recommended as they are liable to discolouration and failure from electro-chemical action. Such joints are not necessary when welding can be conducted easily.

Polishing.—This is an easy operation carried out in the normal manner. The pressure applied need only be comparatively light and the strokes long and gentle.

Pressing, Spinning and Deep Drawing.—Any productions of this type can be made from the soft standard "Birmabright" sheet or the specially ductile "H" quality of sheet developed for this purpose.

Machining.—The various operations present no difficulty. Turning, milling, boring, sawing can all be carried out with facility.

Anodising.—The alloy anodises excellently by any of the commercial processes, with the production of a particularly tough film. The "colourless" nature of the film renders anodised metal very suitable for decorative work.

Casting.—The metal can be sand, gravity, or pressure die-cast. Many foundries are licensed to use the alloy ingot for casting purposes.

From these typical descriptions it can be seen that the manipulation of "Birmabright" presents no difficulties and that it can be successfully worked even by comparatively unskilled labour.

Fatigue Strength of Wrought Aluminium Alloys

VERY little data is available regarding the fatigue strength of aluminium alloys ; investigations on wrought aluminium have been concerned mainly with the determination of the alternate bend strength, using rotating test pieces. Less data is available on the fatigue strength of sheet material, though recently tests on wrought aluminium alloy sheet specimens were carried out to determine the effect of different experimental conditions on the fatigue strength obtained with flat bend test pieces and some results were obtained for the tension-compression fatigue strength.

Development and Research in the Russian Aluminium Industry

By A. Behr, B.Sc.

Although the aluminium industry in the U.S.S.R. has had a comparatively short existence it has raised its production from the modest output of 900 tons in 1932 to an output computed to exceed 40,000 tons in 1937; even with this progress, however, imports indicate that consumption exceeds production. A noteworthy feature of the development of the aluminium industry in this country is the large amount of research work carried out and in progress, on both laboratory and commercial scale, from which it may be inferred that the structure of the industry is on a sound basis.

NEGLECTING pilot plant production, starting from about 1929, it may be said that aluminium was first produced on the commercial scale in the U.S.S.R. in 1932, in which year the output was 900 tons. This was at the Volkhov aluminium works, situated about 75 miles east of Leningrad. The works include an alumina plant in which bauxite obtained mainly from the Tikhvin bauxite deposits is worked up. The output capacity for aluminium amounts to 10,000 tons and for alumina to 20,000 tons per annum.

The second aluminium works at present in operation is the Dnepr Aluminium Combine which, in addition to the reduction works (estimated capacity 40,000 tons p.a.), includes an alumina works and carbon electrode and cryolite plants. Bauxite is supplied from the Tikhvin deposits and also from the more recently discovered high-grade bauxite deposits in the Ural mountains. Both the Volkhov and the Dnepr works are supplied with electrical energy from hydro-electric generating stations nearby.

Two other units of the Russian aluminium industry are the Polevskoi plant in the Urals for the manufacture of aluminium fluoride and synthetic cryolite and the Moscow electrode works, which manufactures carbon electrodes and carbon blocks for furnace linings. Mention must finally be made of the Aluminium Combine (reduction, alumina and electrode works) at present under construction at Kamensk in the Ural district. It is intended to use exclusively the local high grade bauxites for the production of the alumina, which will be produced by the Bayer process.

The modest output of 900 tons in 1932 rose rapidly to 4,400 tons in 1933 and to 14,400 and 24,500 tons in the following two years. No official figures for production have been given after 1935, a conservative estimate for 1937 being 44,000 tons. Consumption has, however, outpaced production as is shown by the import figures which, after falling from 20,000 in 1931 to only 34 tons in 1936, rose to 2,500 tons in 1937 and to as much as 5,800 tons during the first eight months of 1938. Imports of alumina on the other hand have practically ceased since 1936.

Reduction and Production

As far as the reduction end of the aluminium production is concerned, practice at both the Volkhov and the Dnepr works follows conventional lines. The 24,000 amp. Sabart type furnaces originally installed have been partially reconverted to take up to 35,000 amps. For this purpose the number of anodes was increased from 14 to 16, double contact aluminium jacketed anodes being used. The number of cathode blocks was increased from 24 to 32, at the same time increasing the cross-section of the iron bars through which the electric current is supplied to the furnace bottom. Certain modifications had also to be made in the lining of the furnace walls, primarily with the object of increasing the heat losses. As a result of these changes, the cathodic and anodic current densities in the intensified furnaces were only slightly higher (0·87 to 0·93 amps./cm.^{2} and 1·13 to 1·23 amps./cm.^{2} respectively) as compared with those of furnaces operating with the lower current strength (0·6 and 1·07 amps./cm.^{2}). The slight increase in the potential across the furnace and, consequently, slightly higher energy consumption per kg. of aluminium produced, resulting from intensification, it is claimed, are fully compensated by the greatly increased output capacity.

The Ural aluminium works, when completed, will be equipped with the modern type of closed furnace, each provided with one self-baking electrode operating on 50,000 amps. Advantage will be taken of the possibility offered by this type of furnace of recovering fluoride compounds from the furnace gases.

In spite of the comparatively short existence of the aluminium industry in the U.S.S.R., a surprisingly large amount of research has been carried out, and to a large extent freely discussed in the technical press, on various aspects of the production process, both on the industrial and laboratory scale.

A number of careful measurements have been made on several occasions of the energy balance of reduction furnaces and the various items making up the waste energy losses have been carefully checked up and their elimination considered. The possibility of operating furnaces without anode effects came up for early consideration and a satisfactory method of suppressing them by careful attention to the furnace and controlled additions of alumina was developed. Electrical resistance losses in the bed-plate led to the consideration of the liquid cathode type of furnace, of which several types were suggested, built and tested. Attention has also been devoted to the replacement of carbon in the lining of the furnaces by other materials and in this connection magnesite- and corundum-lined full scale Straube type furnaces were constructed and tested under service conditions for a period of six months, encouraging results being given by the magnesite-lined furnace.

Production Research

Perhaps the most interesting research in this field, however, is the work by Belyaev on the use of non-combustible electrodes in the electrolytic production of aluminium from cryolite-alumina melts. Working on a laboratory scale, it was first found that the majority of the chemically resistant metals which could be used economically for this purpose were unfit owing to their being more or less rapidly attacked by the molten electrolyte. In later investigations Belyaev turned his attention to electrodes made of compressed and sintered metallic oxides, with some of which quite satisfactory results were obtained. Pure oxides were subsequently replaced by electrodes made of ferrite compounds, the resistance of which to attack by the electrolyte was found to be even greater than that of the pure oxide electrodes. The best results were obtained with electrodes consisting of tin ferrite, cobalt ferrite and iron ferrite (magnetite). The electrical resistance of these electrodes decreases rapidly with rise in temperature and reaches quite low values

(0·55 ohms./cm.^{3} for cobalt ferrite) at the temperatures encountered in aluminium furnaces (about 850° C.). Experiments carried out using these electrodes, apart from their inherent primary interest, have also thrown some light on the mechanism of the electrolytic process, the study of which is facilitated owing to the absence of secondary reactions at the anodes.

The complex problem of the manufacture of carbon electrodes and carbon blocks has been tackled mainly from the point of view of correlating their structural characteristics with mechanical and physical properties. The former were either arrived at by varying the proportions and characteristics of the ingredients (coke, anthracite, pitch binder, etc.) in manufacturing electrodes which were then subjected to mechanical and physical tests; or by a microscopic study of finished electrodes, the composition of the raw mix being arrived at, for example, by planimetric measurements. This simple microscopic examination, using in some cases polarised light for identification purposes, has proved very informative, particularly when used to compare electrodes of different origin.

At the time of construction of both the Volkhov and the Dnepr works, only the low grade bauxite from the Tikhvin mines was available and the alumina processes at both works were therefore specially adapted to deal with this ore, which contains 12 to 16% silica. A modified dry soda calcination process was originally used at the Volkhov plant, while a thermal smelting process, resembling the Pedersen process in principle, was worked at the Dnepr plant. Both processes have been modified during the course of operation. Before the discovery of high grade bauxite in the Urals in 1932, various processes were worked out in the Soviet Union for extracting alumina from nepheline, leucite, alunite and clay, huge deposits of these ores, estimated at many hundred millions of tons, being available. Particular attention was given to nepheline and research work on methods of working up this ore has been published by the laboratory of the State Institute for Applied Chemistry.

As a result of a very large amount of work on various types of raw materials other than bauxite and both acid and alkaline extraction processes, the general conclusion arrived at was that although extraction of alumina from the majority of these ores is technically possible, one cannot obtain alumina at a lower cost than that involved in the extraction of good quality bauxite.

As has been mentioned above, the Bayer process will be used at the Ural aluminium works and the planned minor improvements include the wet grinding of unroasted bauxite, the operation of—possibly continuous—autoclaves at pressures of 100 to 120 atmospheres, the production of a rather more concentrated than usual sodium aluminate solution and the speeding up of the "seeding out" process.

A very considerable amount of research work has been carried out at the All-Union Aluminium-Magnesium Institute on the properties of sodium aluminate solutions, which form the final product of all alkaline alumina processes. The stability of these solutions has formed one of the chief subjects of investigation, in which factors influencing stability of aluminate solutions were studied. Reference may perhaps be made to the interesting discovery of the stabilising action of alkaline peat extract solutions (containing the sodium salts of humic acids) on aluminate solutions. This effect, although preventing the decomposition of the sodium aluminate during handling, was found not to interfere with the precipitation of hydrate by treating the solution with carbon dioxide. Some valuable work has also been done on the types of hydrate precipitated under varying conditions from aluminate solutions of different concentrations.

Alloy Research

Turning now to what may be termed the consumption side of the industry, one notes the almost complete absence in the Russian technical literature of the type of article on the applications of aluminium and its alloys so frequently encountered in the technical journals of other countries. Consumption of aluminium in the Soviet Union is restricted, at present, to the heavy industries—primarily aircraft construction, transport and electrical industries. Alloy research, a great deal of which has been carried out, notably at the Scientific Research Institute for Aircraft Materials and the Central Aero-Hydrodynamical Institute, has been devoted mainly to known alloy compositions (chiefly, of course, Duralumin, including Alclad, and the standard Cu- and Si-containing foundry alloys) and had for its object a thorough study of the effect of minor variations in composition on the corrosion-resistance and mechanical properties. Correct working conditions and annealing and heat-treating temperatures were also established.

In connection with corrosion tests, the comparatively little known work by Akimov and Oleshko at the Institute for Aircraft Materials may perhaps be mentioned. Their work (published in 1934) on the structural corrosion of aluminium alloys included, in addition to continuous microscopic observations of the corrosion process, a measurement of potential differences between aluminium and common alloy constituents such as Al_2Cu, $MnAl_3$, $FeAl_3$ and between Al-Mg-Si solid solution and the compound Mg_2Si.

The almost completely neglected problem of the effect of sulphur and phosphorus contained in aluminium and aluminium alloys on their corrosion resistance, as well as the tendency of these two elements to liquate and accumulate in certain alloy constituents, has recently been studied in an exhaustive fashion by Tutov.

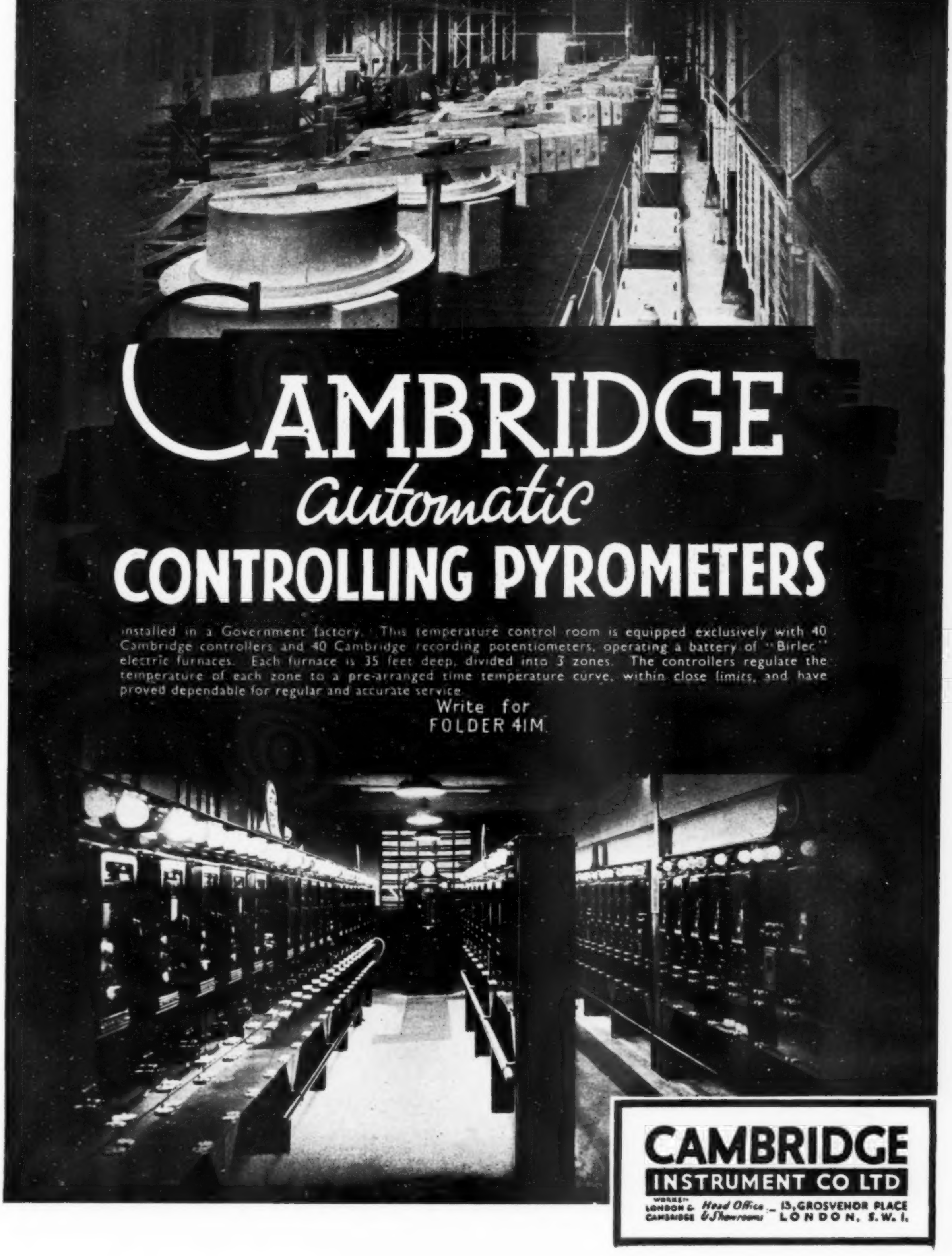
Some valuable contributions to the work relating to non-metallic inclusions (Al_2O_3, SiO_2 and gases) have been made by the research of Klyachko. Space does not permit reference to the theory advanced by Klyachko to account for the gas content of aluminium, its variation in aluminium alloys and its behaviour during the vacuum hot-extraction method of analysis. The same theory has been applied to explain the objectionable phenomenon of blistering of aluminium, and aluminium alloy sheet during heat-treatment and the method of preventing it by the use of an atmosphere capable of oxidising nascent hydrogen, suggested by Klyachko, is in agreement with this theory.

In conclusion, the research by Plotnikov and his collaborators on the electrochemistry of non-aqueous solutions, including a large number of solutions of aluminium salts, must receive some mention. The same investigators have developed possible methods of refining aluminium using electrolytes with melting points below the melting point of aluminium. One of these methods, in which an aluminium chloride-sodium chloride melt is used as the electrolyte, has found commercial application for the aluminium plating of copper conductors.

In appraising Russian research, one must bear in mind that, in addition to the obvious value of original research in new fields, a considerable value attaches to work of a more or less repetitive nature as in many cases it has brought out some new aspects of what were regarded as "well-known" facts and has raised queries regarding the justification for some "firmly established" processes. At the same time one must acknowledge the frank publication of research details and results which elsewhere would have either remained unpublished or made their appearance only in the form of technically vague patent specifications.

Temper of Aluminium Sheet

There is a considerable difference between aluminium sheet in the work-hardened condition and that softened by annealing. For aircraft purposes the B.S.I. specifications standardise three different tempers: Hard, with a tensile strength of not less than 9 tons per sq. in.; half hard, with a strength of 7 to 8½ tons per sq. in.; and soft, with a strength of 5 to 6½ tons per sq. in.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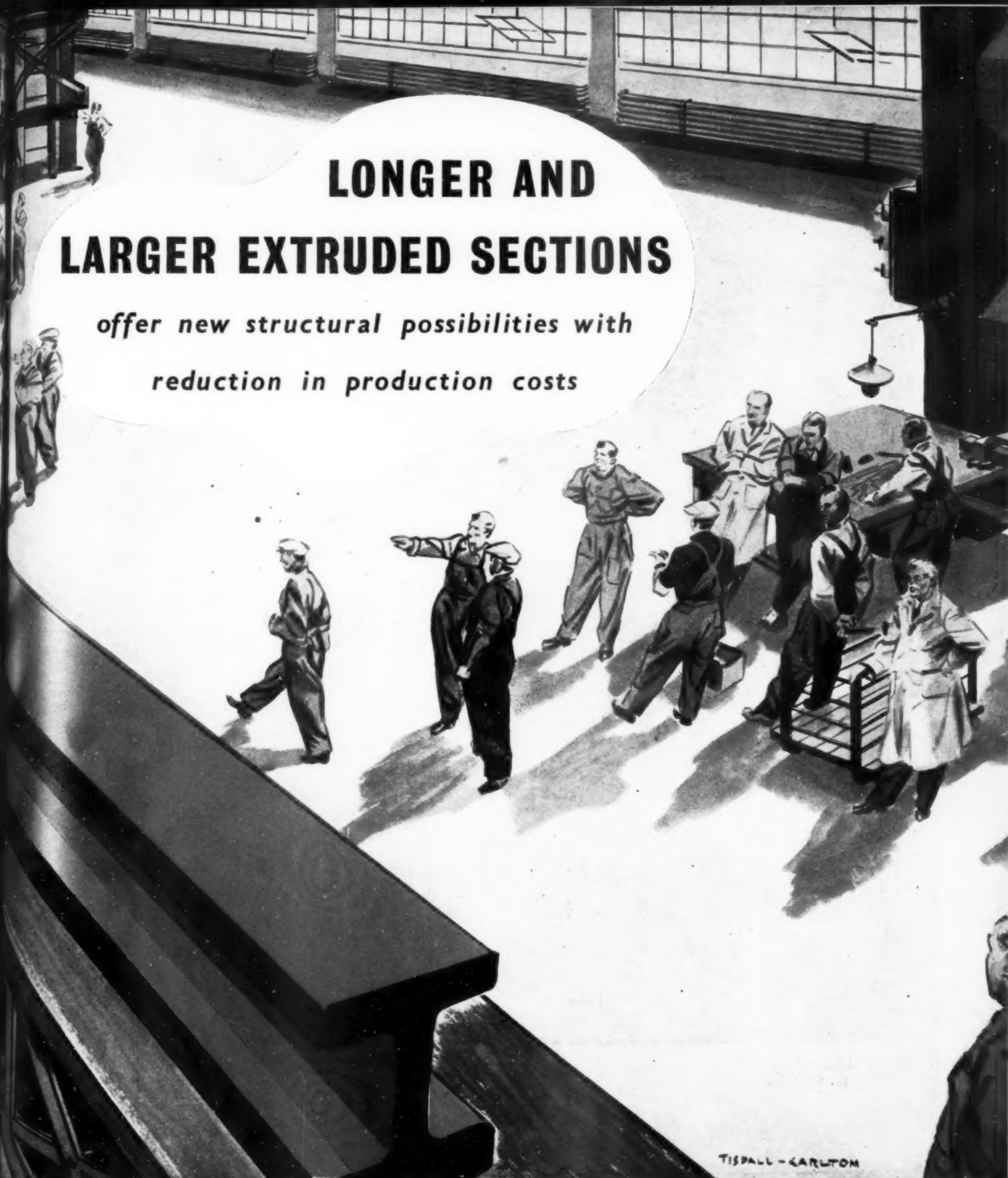

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The Spraying of Metallic Aluminium

Investigations have shown that the corrosion resistance properties of aluminium can be used successfully to protect other materials which are readily attacked under corrosive conditions, and excellent results are obtained from sprayed aluminium. In this article the process is described, and reference made to several applications, especially for use on surfaces of parts to be used at elevated temperatures.

By W. E. Ballard

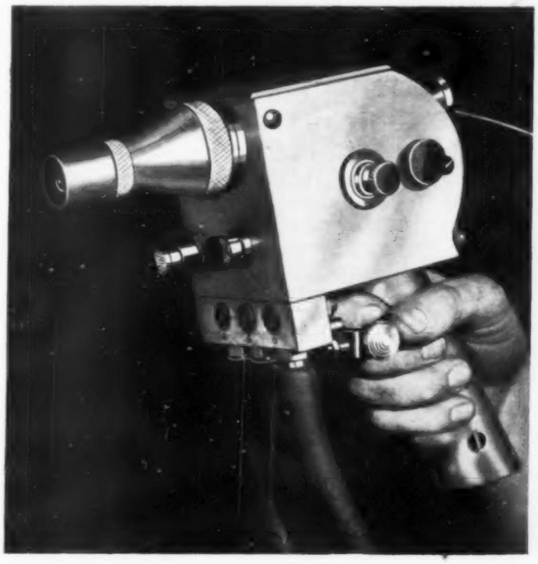
IN the early days of the aluminium industry very mixed experiences were obtained with articles manufactured of aluminium when they were exposed to conditions which were mildly corrosive. Some prejudice even exists to this day against aluminium because of these failures. It is therefore a surprise to some engineers to hear of a thin coating of aluminium being recommended as a protection to steel against atmospheric and marine corrosion.

Nevertheless, taking an extreme case first, aluminium coatings which have been sprayed from wire have been found to give very good protection to cast-iron propellers of trawlers. These propellers are well known to be subject to very intense cavitation, and yet over a period of a year a coating of 0·004 in. of aluminium of a purity above 99·8% was found to protect a propeller almost completely.

It is probable that Dr. U. R. Evans, of Cambridge, was one of the first independent observers to report on the excellent results obtained from sprayed aluminium as a protection to steel, but his work was closely followed by reports from Dr. Sutton, of Farnborough, giving similar results. Dr. Evans and Mr. S. C. Britton exposed steel plates coated with aluminium by the wire process of spraying to various types of atmospheres at different sites in this country. Interim reports on the behaviour of the specimens have appeared in various scientific journals, and the final report of seven years' exposure will appear shortly in the *Journal* of the Society of Chemical Industry. To sum up in a few words the results of these workers, it can be said that aluminium coatings applied by the wire system appear to prevent the corrosion of iron and steel over long periods, although some alteration of the aluminium is noted at the end of seven years; no advantage is obtained by covering these coatings with layers of synthetic varnish, but that lanoline and paint appear to give added protection to such layers, especially in the case of industrial atmospheres.

From its position in the electrochemical series, aluminium would be expected to be very anodic to iron and steel, and therefore its protection would be by sacrificial action, as is the case with zinc coatings. Undoubtedly the anodic properties of aluminium do play a certain part, but it is safe to say that the major protection is given in the case of this metal because of its property of forming hard films of its corrosion products which resist further attack. The matte surface obtained by metal spraying, together with the presence of some porosity of the coating, evidently gives an ideal surface on which such films build up and can remain intact. That electrochemical action also is present appears to be borne out by the experiments of Evans and Britton when specimens were scratched through the aluminium coating, and were found to suffer very little damage as attack commencing at the scratches quickly prevented further attack.

The scientific data which are now available have quickly been turned to commercial use, and comparatively thin coatings of sprayed aluminium are being used extensively for the protection of steel structures. The Air Ministry Specification D.T.D. 906 calls for such coatings sprayed by the wire system for the welded steel parts of aircraft, such as engine bearers, etc. The comparative lightness of the coating is also an advantage in such circumstances.



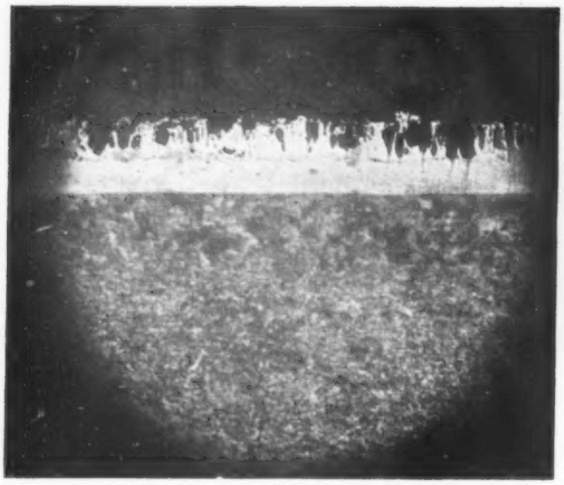
Mark 16 pistol, a new type recently introduced by Metallisation Ltd.

New Type of Pistol

There is no doubt that in many instances metal spraying provides the only really commercial means of obtaining such coatings, and as it appears to be certain that high purity is extremely desirable the wire pistol represents the ideal tool for application. The metal-spraying tool or pistol is very well known, and has been described in detail in the technical press on many occasions. It is therefore not necessary to give here a full description of the pistol except to remark that a new type of pistol has been recently introduced by Metallisation, Ltd., known as the Mark 16 pistol.

This tool follows the general rules of construction of gas-fed pistols, and consists of three main members, of which the most important is the nozzle. The nozzle consists of a nichrome tipped slightly conical inner tube through which aluminium wire, from 1 to 2 mms. in diameter, is fed. This tube carries round its external surface grooves which when covered by a cap serve to convey an almost explosive mixture of a fuel gas and oxygen under a pressure of from 15–25 lb. per sq. in. If the mixture was ignited at the nozzle tip it would form a blowpipe flame into the centre of which passed the wire, which would melt in the hot zone and fall away in drops. Round the gas nozzle, however, is placed another cap, so that between them compressed air at from 35–60 lb. per sq. in. pressure can be passed to the jet. This causes an envelope of compressed air to form round the flame, and the melting wire is caused to form a spray of fine particles of about 0·001 mms. diameter.

The wire is fed through the nozzle by means of rollers driven by a train of gearing activated by a compressed air



Photomicrograph of an aluminised coating on steel.

turbine contained in the tool. The feed of the gases and air to the jet and the air to the turbine is controlled by a composite valve with one control. The fuel gases used in this country are usually coal gas or propane. The Mark 16 pistol is very robust in construction, and its refinements include an extra large turbine, wire-tensioning device, external control of wire rollers, and special type of valve.

Spraying Conditions

The surface to be metal sprayed must be cleaned and roughened by shot-blasting, and this is usually carried out with an air pressure of from 30–50 lb. per sq. in., and angular steel grit must be used to obtain the roughness necessary for adhesion.

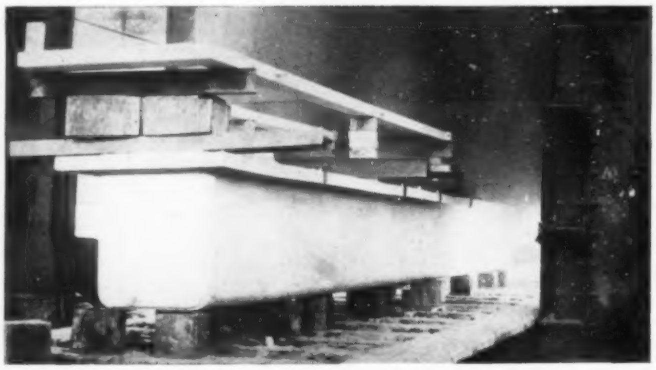
At the working distance of 5 in. from the nozzle, the spray is nearly cold, and no distortion or loss of temper is to be feared. There is no alloying of the aluminium to the base metal, but the adhesion is remarkably good.

The pistol under favourable conditions will spray 3–5 lb. of aluminium per hour, and it is inadvisable to construct a nozzle giving greater deliveries owing to excessive oxidation at high speed. The loss during spraying of aluminium is comparatively low, being at the most 7% when spraying plane surfaces. The thickness of the coating can be arranged and accurately checked by means of an electro-magnetic thickness tester.

Applications

The aluminium coatings produced in this manner are of a matte finish, with a very white colour, which is highly reflective for a matte surface. They are being used for decorative effects on buildings, and give pleasing effects in flood lighting. They are resistant to attack by sulphurous gases, and have been used for coke cars in by-products ovens. The protection of gas holders by this method is also a matter of particular interest, as the coatings are not attacked by the pollution products in the water seal. The coatings also resist well the action of moisture-bearing petrols, and this is particularly noticeable in the case of doped fuels. By throwing the pistol slightly out of adjustment, a rough coating is obtained which has found commercial application for the walkways of aircraft and motor-boats, as it gives a non-slip finish.

As might be expected, coatings of aluminium applied by spraying also protect iron and steel against moderate heat. Up to temperatures of 500° C. the aluminium coating is quite suitable in the as-sprayed conditions. The use of this coating enabled very considerable development in the multiple inverted type of burner, as is used in gas street lighting. The coating prevents the formation of the heavy deposits of scale due to sulphur attack at high temperatures, and therefore prevents mantle breakage. These remarks apply equally to burners made of brass or steel, and hundreds of thousands have been treated. The process is also used for many gas stove parts.



A nitrate pot, 35 feet long, entering furnace for aluminising.

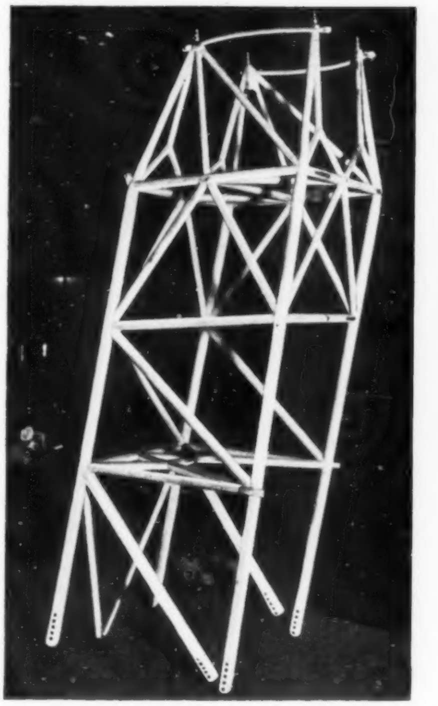
Coatings for use at Elevated Temperatures

At more elevated temperatures the coatings of aluminium are still of great commercial value, and in this field very rapid commercial development has taken place and greater developments are likely. The process is slightly modified to meet the necessities of high-temperature conditions, and is known in this country as aluminising. The various methods used are patented. The fundamental difference is that the coatings as sprayed are subjected to heat-treatment at temperatures varying between 750° and 900° C. under various furnace conditions. The aluminium coating, usually applied to a thickness of between 0·006 in. and 0·008 in. in thickness alloy with the steel base at these temperatures, and coatings of dull grey colour, which consist of gradations of iron aluminium alloys, are formed. This surface regenerates films of aluminium oxide which are extremely protective at high temperatures. Even cast iron can be so treated, although the results are not so good as with steel, but the life of the article is greatly increased, especially if the article is cast in an iron which is subject to the minimum of growth. At temperatures exceeding 950° C. the life of aluminised coatings decreases rapidly as the aluminium is absorbed so rapidly by the underlying metal that the surface becomes quickly impoverished. This method of heat protection is very convenient, especially for large articles, which would be difficult to treat by the cementation processes in which packing in powder in heated drums is necessary. It has been used extensively for aircraft manifolds in accordance with the Air Ministry's Specification D.T.D 907. In this case, after furnacing, the articles are wire brushed, giving a very pleasant silvery finish, which is retained at high temperatures.

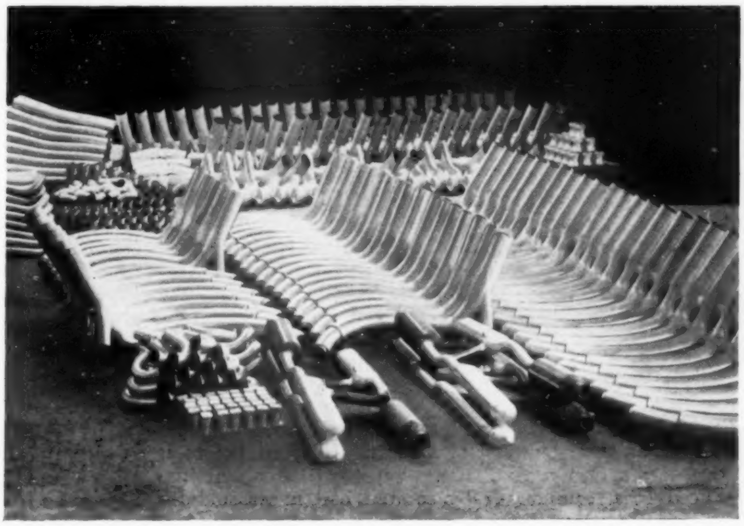
The advantages offered by aluminising have been quickly realised commercially, and the tonnage of aluminium wire used for this purpose is considerable. Many parts of modern industrial furnaces are so treated and give very long life. In a metallurgical journal it is hardly necessary to enumerate the articles which are giving useful service because of this process, but hardening boxes, annealing covers, pyrometer sheaths, deflector bowls and some types of ladle may be mentioned.

An application of aluminising of special metallurgical interest is the protection of the steel baths used for treatment of aluminium articles in molten mixtures of nitrates. The coating is effective both externally in the heating zone and internally in contact with the heated nitrates themselves.

Briefly, therefore, it can be said that this process has been proved to give protection to steel articles at elevated temperatures, so that the increased service obtained pays many times over for the cost of application. The method, however, cannot be recommended where the surface treated comes into contact with fusible substances of alkaline reaction which flux with the oxide coatings produced.



Engine nacelle sprayed with aluminium.



Aircraft manifolds which have been aluminised in accordance to the Air Ministry's Specification, D.T.D.907.

This explains why aluminising is not suitable for all types of firebars, especially those where the fuel leaves a fusible ash.

There is a distinct possibility that metal spraying will give at least one outlet for the use of the very high purity aluminium which is now available commercially. Experiments are proceeding which seem to indicate possibilities in this direction, especially where chloride attack is fairly severe. It can be stated that, in general, to get the best out of metal spraying of aluminium it is advisable to use the highest purity of wire which is available, taking into consideration the cost of the various types of wire.

The spraying of aluminium alloys is also a field of considerable interest. Sprayed Birmabright, for instance, gives a coating which, when polished, retains its white lustre under adverse conditions. In Germany, Hydronalium, polished after spraying, is used as a substitute for chromium plating, but of course this is due largely to the control of chromium in that country. Nevertheless, several of the alloys of aluminium when sprayed possess properties which can be of considerable service under specific conditions. The wire process of spraying can be used for all metals or alloys capable of being drawn into wire and melted in the oxy-acetylene flame.

There are two other systems of metal spraying in operain this country, but up to the present they have been concerned mainly with the spraying of zinc. The Mellowes pistol makes use of molten metal, the metal being ladled into the tool and kept hot by means of a flame in the tool itself. The molten metal passes into a nozzle and is sprayed with a stream of air. I am informed that a recent development of this pistol which shields the operator from the working part allows of the spraying of aluminium of high commercial purity.

The other process makes use of metal powder as the raw material, and is known as the Schori system. The metal powder is aspirated by air through the pistol flame and becomes heated by it. A stream of compressed air on the outside of the flame causes the spraying action. This system will deal with almost any metallic powder of suitable grade—viz., about 200 mesh,—and I understand that powders of a very high standard of purity are obtainable.

In conclusion, it is hoped that this brief contribution will give a general idea of the development of metal spraying and of the rapidly growing use for metallic aluminium by this process.

Aluminium Paint

THE use of aluminium paint is becoming common practice in many works in connection with various types of plant and machinery. Unlike other paints, aluminium paint consists of very small leaves of aluminium which when applied to suitably prepared surfaces interleave and provide a continuous protective metallic sheath. After exhaustive trials it has been introduced as a standard paint for marine purposes, and in certain classes of vessel, where weight is an important factor, a considerable saving in weight is effected by its adoption. The paint is used both as a priming and anti-corrosive undercoat for steel work, where the prevention of rust is of primary importance, and as the final coating in such places as store-rooms. In spaces not unduly exposed to moisture, aluminium paint has proved entirely satisfactory, providing a suitable vehicle is used in mixing it and the surfaces to which it is applied are properly cleaned.

Aluminium paints are not only light in weight, in comparison with other paints, but they are also more resistant to corrosion and have a higher opacity and reflecting power; they have also a good appearance, are easily applied, and assist internal lighting. In some instances boilers are coated with aluminium paint to reduce heat losses. Due to development in applications, the demand for aluminium paste has continued to increase very rapidly both for incorporation in the normal type of aluminium paint and also for priming paints.

A new grade of aluminium paste of very fine texture is now being produced by the Northern Aluminium Co., Ltd. The covering area of this new pigment, as determined by a water flotation test, is double that of the standard grade paste first developed for general purposes. In its finest form this paste gives a finish of extremely smooth texture, having the appearance of silver enamel. It is also noteworthy that a filler paste, consisting of a quick-drying metallic mixture embodying aluminium paste, has recently been developed by Messrs. Bryce, Weir and Co., Ltd., under the guidance of the Northern Aluminium Co., Ltd., for aircraft, and is finding increased use for the filling of rivet indentations and also metal joints, with the object of improving stream-lining.

Long-Term Prices of Aluminium

By Robert J. Anderson, D.Sc.

The extent to which aluminium can be used for many purposes is governed largely by its cost in comparison with other metals. To obtain a reasonable basis for such comparison, price relations based on volume are more representative of comparative costs in the case of metals which differ considerably in density. In this article the author examines the relations of selling prices for aluminium and several other non-ferrous metals on the basis of both weight and volume, and shows that on the latter basis aluminium is in a strongly competitive position. The trend of prices for this metal are also discussed.

ALUMINIUM was first prepared in 1825, but more than three-quarters of a century elapsed before it came into general use. Up to 1889 aluminium reduced from compounds by sodium had never sold for less than \$4 (say 16s.) a pound, and consequently could not be employed in competition with common metals. The invention of the Hall-Héroult electrolytic process (1886-1889), and its subsequent development on a large industrial scale made possible the production of aluminium at relatively low cost.

World output of primary aluminium was gradually increased, and the selling price was substantially reduced during the early years of the modern industry. The price remained comparatively high, however, until about 1900, and consumption was accordingly restricted. Of course, the utilisation of aluminium was limited for a considerable period—namely, for about 20 years after the electrolytic method had been put into operation—because of other reasons apart from price. For example, the metal was new and its fields of practical application were either not well known, or else not satisfactorily proven. Besides, sundry industries which were later to become large consumers of aluminium were then not far advanced, and others had not been undertaken. Moreover, the mechanical properties afforded by primitive aluminium alloys were so inadequate that these materials were unsuitable for various structural purposes.

The World War marked the beginning of widespread interest in aluminium, and demand then started to increase rapidly. During the war period many new uses were found for aluminium, and it was employed in numerous applications as a substitute for other metals. Also, much important research work was begun at this time by aluminium producers, governmental bureaus, and other organizations. New information concerning the properties of the metal was made available, and later the heat-treatment of both wrought and cast aluminium alloys was developed. Furthermore, various manufacturing processes were improved, and costs were reduced with increased output. As a result of advances during the war the field of use for aluminium was greatly enlarged. Especially notable progress has been witnessed in the last 10 years. Aluminium is now one of the major non-ferrous metals, and for some time it has been competitive on a price basis, or owing to technical superiority for particular purposes, with copper, tin, and other metals as well as certain non-metallic materials.

The history of aluminium prices has been recounted by the writer[1] in another place, especially with regard to fluctuations in the United States, Germany, and the "world market." Also in the discussion there, the various factors which have affected the selling price generally, and at different times were examined. These factors include output, tariffs, cartel control, demand, governmental regulations, costs of production, business conditions, and competition with other metals. In addition, the difference of prices as among the most important producing and consuming countries was noted. Ferrand[9] has studied the course of aluminium prices in France, particularly in relation to copper prices and the cost of producing aluminium in that country. These two papers may be consulted for detailed information concerning the development of prices over the long term.

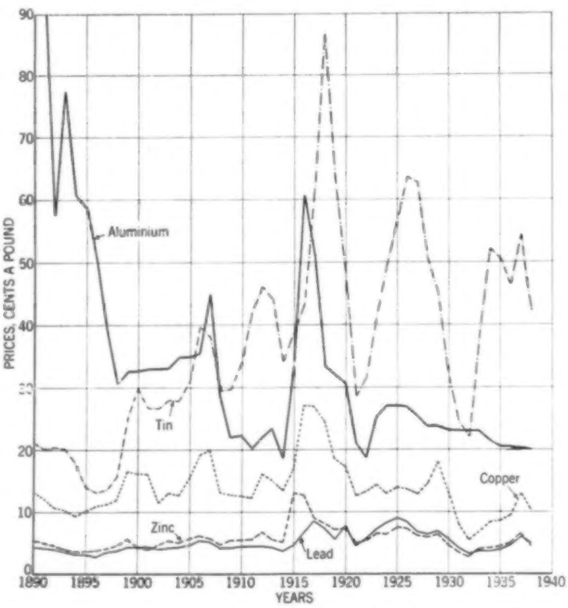


Fig. 1.—Average selling prices of the principal non-ferrous metals in the United States, 1890-1938 ; weight basis.

It suffices here to mention only a few outstanding matters which have had influence on the market. More apposite to the present purpose is a comparison of selling prices for aluminium and other non-ferrous base metals since the introduction of the Hall-Héroult process. At the same time, the outlook for aluminium prices may be considered to advantage. It is being affected markedly by well-defined trends in political economy as well as by innovations in metallurgical and engineering practice.

As was emphasised in a recent paper[4], price relations based on weight may be fairly representative of comparative costs in the case of metals which do not differ much in density. But to compare the price of a light metal (aluminium, density 2·7) by the pound or ton with that of a heavy metal (copper, density 8·9) is fallacious. The price should rather be compared in terms of unit volume. In this connection the relations of selling prices

1 Anderson, R. J. "Die Entwicklung der Aluminiumpreise seit 1825." *Metallwirt*, vol. 16, 1937, pp. 353-8 ; 406-9.

9 Ferrand, L. "Le Problème des Prix dans la Métallurgie de l'Aluminium." *Rev. d'Econ. Politique*, vol. 51, No. 2, 1937, pp. 297-330.

4 Anderson, R. J. "Long-term Growth of World Aluminium Output." *Metallurgia*, vol. 18, No. 105, 1938, pp. 87-90.

for aluminium and several other non-ferrous metals on the basis of both weight and volume have been examined over the period of the last half century. The results are portrayed graphically in Fig. 1.

Course of Prices

Nearly all selling prices considered here are the annual averages for the United States. These are based mostly on quotations in the New York market. In the case of aluminium the prices represent the so-called outside market (New York) as determined mainly by transactions of importers, and may differ more or less from the averages derived from quotations by the Aluminium Company of America. Still, except in some years, the two averages have been fairly close during the term under review. In 1915, 1916 and 1917 the average prices for primary aluminium in the outside market were 33·98, 60·71, and 51·59 cents a pound, respectively. The average contract prices of the Aluminium Company of America for these years have been estimated at 32, 34, and 37 cents. Prior to 1930 the New York averages are for primary aluminium of 98 to 99% grade, and thereafter for the 99+% metal.

With reference to copper prices, the averages for the years 1890-1898, both inclusive, are for best selected metal in London. The prices in £ sterling a long ton were converted to cents a pound at exchange parity. Otherwise, the averages are for electrolytic copper, New York. In the case of zinc the averages apply to ordinary Prime Western brands in New York for the years 1890-1919, both inclusive, and in St. Louis for 1920 onwards.

In all cases the prices subsequent to 1932 are in terms of paper currency.

The selling price of aluminium in both Europe and the United States declined greatly over the decade following 1890. Producers were enabled gradually to offer the metal at decreasing prices as costs were substantially reduced during this period. In the span 1901 to 1907 the price rose markedly. This advance was due in part to increased demand accompanying the cyclic upswing in business at that time, and in part to influence of the first international aluminium cartel which was formed in 1901. Prices dropped sharply with the onset of the industrial depression in 1907 and collapse of the cartel. This decline continued during the period 1907 to 1911. Prices improved appreciably from 1911 to 1913, receded in 1914, and then advanced rapidly as demand increased during the World War. The second international aluminium cartel was established in 1912, but ceased to function shortly after the war began. Improvement of prices in 1912 and 1913 was due in part to control by the cartel. Various Governments fixed aluminium prices in the war period.

Governmental controls were annulled at the end of the war, but prices remained high for two years thereafter. The market was then influenced by the post-war industrial boom and by non-military demands which had been unfilled during the war. With the retrogression of trade beginning in 1921 prices fell quickly, and in the United States the average for 1922 nearly reached the all-time low point of 1914. In these years the average price was about 18½ cents a pound. The minimum of the averages in European markets was reached in 1911 when it was approximately the equivalent of 12 cents. Since 1924 the trend of prices has been generally downward within national boundaries and with respect of both gold and paper currencies. One exception is France, where prices have been advanced, partly on account of the monetary devaluations.

In connection with the trend of prices it may be noted that the bulk of primary aluminium has been marketed under cartel control for some years. The policy of the third international cartel (organized in 1926) and its successor, the Alliance Aluminium Cie (founded in 1931), has been gradually to lower prices. Also, the Aluminium Company of America has announced a policy of selling the metal as cheaply as possible.

Fig. 1 shows the course of selling prices by weight for aluminium, copper, lead, tin and zinc in the United States over the 49-year period 1890 to 1938. The graphs were constructed by plotting the annual averages in cents a pound. As may be noted, the selling price of aluminium, on the basis of weight, has continued to exceed that of the other metals with the exception of tin. In the period 1900 to 1938 the average price of aluminium was, however, appreciably to considerably less than that of tin in all years but nine (1900 to 1905, both inclusive, 1907, 1915 and 1932). Too, the relative stability and downward trend of aluminium prices since 1925, as contrasted with the fluctuations in prices for the other metals, is to be remarked.

As concerns long-term trends and the relative stability of prices some average figures for the several metals may be compared. For the five-year period, 1901 to 1905, the approximate average prices of aluminium, copper, lead, tin, and zinc were as follows: 33·80, 13·89, 4·33, 28·19, and 5·05 cents a pound, respectively. And for the five-year period, 1934 to 1938, the corresponding prices were: 20·53, 9·99, 4·68, 49·12, and 4·90 cents. Thus, in the latter period, the average selling price of aluminium was about 39% less than in the former period, that of copper was 28 per cent. less, of lead 8% more, of tin 74% more, and of zinc 3% less.

For the 15-year period, 1924 to 1938, the approximate average prices of aluminium, copper, lead, tin, and zinc were, respectively, 23·36, 11·34, 5·71, 46·09 and 5·32 cents a pound. And in this period the high and low (approximate) averages were: For aluminium, 27·19 and 20 cents; copper, 18·11 and 5·56; lead, 9·02 and 3·18; tin, 63·62 and 22·02; and zinc, 7·62 and 2·88 cents. Therefore, the approximate deviations from the means were as follows: For aluminium, +16 and −14%; copper, +60 and −51%; lead, +58 and −44%; tin, +38 and −52%; and zinc, +43 and −46%.

Some factors which have affected the long-term pattern of aluminium prices may be considered briefly in passing. Firstly, the structure of aluminium economy has been intrinsically different from that of the principal non-ferrous metals. This affords a partial explanation of the comparative movements in prices. For example, a relatively small number of concerns has been engaged in the primary aluminium industry. Moreover, the metal has been produced almost exclusively from one ore—that is, bauxite; and nearly all aluminium companies own or control their ore supplies. Also, in most industrial countries, the production of aluminium has been in the hands of a dominant, or only one, large concern. By contrast, numerous companies have been engaged in the smelting of other metals or the mining of their ores, or both. Then, too, in dealing with complex ores some by-product output may result from the primary smelting or refining of another metal. This, however, is not the case with aluminium.

Next, the markets for most metals have been affected not only by competition among the leading interests, but also by the output of marginal producers. Competition among the large aluminium companies has been restrained by understandings or cartel arrangements. Few marginal producers have operated in the primary aluminium industry, and sooner or later these were acquired by the dominant companies. For the most part the prices of aluminium have consequently reflected control in contrast to those of other metals which have been influenced more by conditions of supply and demand. Of course, with the rise of autarchy, the development of managed economy, and the extension of cartel arrangements during late years, prices of many commodities have been subjected to an increasing degree of regulation.

Other factors which have affected the selling price of aluminium—either within national boundaries, or on the world market—include the cost of production, import

duties, taxes, demand, and competition with other materials. The effects of these are obvious.

Turning to a comparison of aluminium prices in the United States and Europe the statistics show that the general trends have been similar. On the average, however, American prices have been substantially higher than the European. Since 1900 the mean price of primary aluminium in the United States has been about five cents a pound higher than in Germany. But the mean import duty of the former country for the period 1900 to 1938 has also been approximately five cents. So the difference in prices has been equivalent on the average to the duty.

Current (late 1938) prices for aluminium in four countries are of interest in showing the variations as affected by currency values and import duties among other items. The internal prices for high-grade primary metal were taken as follows: In France, 1,340·60 francs per 100 kilograms; Germany, 133 reichmarks per 100 kilograms; United Kingdom, £94 a long ton; and United States, 20 cents a pound. And the exchange rates used were: 2·63½ cents a franc; 40·10 cents a reichmark; and $4·66½ a British pound. Converted to American currency the prices correspond to the following: In France, 16 cents a pound; in Germany, 24·2 cents; and in England, 19·6 cents.

Weight-versus-Volume Prices

The prices of metals are commonly expressed in terms of a monetary value per unit of weight—as cents a pound in the United States and as British pounds a long ton in England. In considering costs, however, it is generally preferable to compare prices in relation to volume rather than weight. This is requisite when there is much difference of density as in the case of aluminium and the heavy metals. Thus, as pointed out earlier, it is misleading to compare the weight-price of aluminium with that of copper. Instead, the volume-price should be the criterion, disregarding properties of the materials and utility for specific applications.

A given bulk of the common non-ferrous metals weighs about three or four times as much as the same bulk of aluminium. Following are some approximate weights in pounds per cubic foot: Aluminium, 169; copper, 556; lead, 712; tin, 455; and zinc, 443. The prices at which the several metals become competitive—in respect of price alone—may be readily calculated. If aluminium sells at 20 cents per pound, the cost of copper per cubic foot is practically the same at 6·1 cents per pound, that of lead at 4·7 cents, of tin at 7·4 cents, and of zinc at 7·6 cents. The lower these latter figures the more competitive, on a price-mass basis, are the four metals as against aluminium. And, conversely, the higher these latter figures the better the competitive position of aluminium with regard to volume-cost. Of course, the price per unit of volume is only one of the many items to be examined in considering materials for specific applications. At the same time, it is highly important and may often be the determinant.

Fig. 2 shows the course of selling prices by volume for aluminium, copper, lead, tin, and zinc in the United

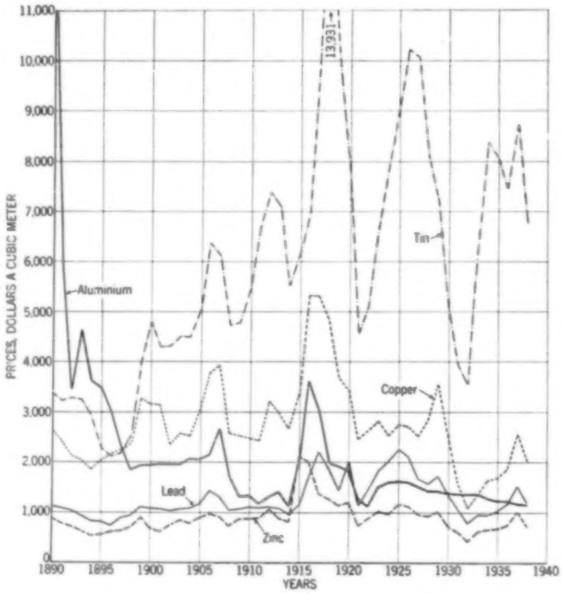


Fig. 2.—Average selling prices of the principal non-ferrous metals in the United States, 1890-1938; volume basis.

States over the 49-year period 1890 to 1938. The graphs were constructed by plotting the annual averages in dollars per cubic metre. In considering costs of the several metals, it is of interest to compare the relative positions of the corresponding graphs in Figs. 1 and 2. The displacement in the case of aluminium, owing to its low density, is especially noticeable. As may be seen, the volume price of aluminium has compared very favourably with that of the other metals, except zinc, for long to shorter periods of time. With reference to Fig. 2 aluminium has cost less than copper in every year, except 1932 and 1933, since 1897. The price of tin has been greater than that of aluminium in all years since 1897. Lead has cost more than aluminium in 11 of the 20 years since 1918. Aluminium has always cost more than zinc.

The long-term trends of prices may again be noted—here in terms of volume, as against the figures for weight previously given. For the five-year period, 1901 to 1905, the approximate average prices of aluminium, copper, lead, tin, and zinc were, severally, as follows: $56.97, $77·16, $30·82, $128·12, and $22·36 per cubic foot. For the five-year period, 1934 to 1938, the corresponding prices were: $34·61, $55·50, $33·29, $223·25 and $21·73. And for the 15-year period, 1924 to 1938, the approximate average prices were as follows: $39·38, $63·00, $40·62, $209·47, and $23·58 per cubic foot for aluminium, copper, lead, tin, and zinc, respectively.

Some additional data concerning the long-term relations of selling prices for non-ferrous metals are given in Table I. The figures include the average prices in cents per pound

TABLE I.

COMPARISON OF LONG-TERM PRICES FOR NON-FERROUS METALS IN THE UNITED STATES, 1900-1938.

Metal.	Price range, cents per pound.		Average price cents per pound.	Approximate weight, pounds per cubic foot.	Average price, dollars per cubic foot.	Price ratio.	
	High.	Low.				Weight.	Mass.
Aluminium	60·71	18·63	28·15	169	47·45	1	1
Copper	27·2	5·56	14·46	556	80·34	0·51	1·69
Lead	9·02	3·18	5·43	712	38·65	0·19	0·81
Tin	86·8	22·11	42·18	455	191·71	1·50	4·04
Zinc	13·32	2·88	6·05	443	26·81	0·21	0·57

over the 39-year period, 1900 to 1938, and the corresponding prices in dollars per cubic foot. For the same mass it is seen that copper cost 1·69 times as much as aluminium on the average. In the same way, lead cost 0·81 as much as aluminium, tin 4·04 times as much, and zinc 0·57 times as much on the average for the period.

The strongly competitive position of aluminium, particularly as against copper and tin, is explained in part by the price-volume relations. As a result, aluminium is foremost in direct competition with copper as material for the manufacture of cables used in the transmission of electric current, and also as the main constituent of alloy castings for various purposes. On account of its high cost, tin has been largely supplanted by aluminium for the production of foil. Numerous other instances where aluminium is preferably employed solely or mainly because it is cheaper, volume for volume, than other metals might be cited.

TABLE II.
INDICES OF PRICES FOR NON-FERROUS METALS, 1900-1938.
BASE, 1909-1913 AVERAGE = 100.

Year.	Aluminium.	Copper.	Lead.	Tin.	Zinc.
1900	149	116	99	76	75
1901	150	116	99	68	69
1902	150	83	92	68	82
1903	150	96	96	71	92
1904	159	92	98	71	87
1905	159	112	107	80	99
1906	163	138	129	101	106
1907	205	144	121	97	102
1908	130	95	95	75	81
1909	100	93	97	76	94
1910	101	91	101	87	94
1911	91	89	100	108	98
1912	100	117	102	117	118
1913	108	110	99	113	96
1914	85	98	88	87	89
1915	155	124	106	98	227
1916	276	195	156	111	218
1917	235	195	200	157	152
1918	152	177	168	221	139
1919	146	134	131	161	125
1920	139	125	181	123	131
1921	96	90	103	73	79
1922	85	96	130	81	97
1923	116	103	165	106	113
1924	123	93	184	126	108
1925	124	101	205	145	130
1926	123	99	191	162	125
1927	116	93	154	160	106
1928	109	105	143	128	103
1929	109	130	155	115	111
1930	106	93	125	81	78
1931	106	58	96	62	62
1932	106	40	72	56	49
1933	106	50	88	100	69
1934	98	60	88	133	71
1935	93	62	92	128	74
1936	93	68	107	118	83
1937	91	94	137	138	111
1938	91	73	108	107	79

In 1938 the average (preliminary) prices of the several non-ferrous metals in the American market were as follows: Aluminium, 20 cents per pound or $33·71 per cubic foot; copper, 10·226 cents or $56·82; lead, 4·739 cents or $33·73; tin, 42·216 cents or $191·87; and zinc, 4·613 cents per pound or $20·44 per cubic foot.

Indices of Prices

Table II gives index numbers of prices for the principal non-ferrous metals in the United States over the 39-year period 1900 to 1938. The base of the numbers is the average price in the years 1909 to 1913, both inclusive, this being taken as equal to 100. These indices show that aluminium prices have been relatively more stable than those of the other metals, particularly during he last 15 years. Theyt also show that the price of aluminium was well maintained during the course of the great depression following 1929, while the prices of the other metals declined extremely (cf. Figs. 1 and 2). Thus, the average price of copper in 1932 was only 40 per cent. of the 1909 to 1913 mean, but the price of aluminium was 106 per cent. Similarly, the average prices of lead, tin, and zinc in 1932 were 72, 56 and 49%, respectively, of the base.

The marked advances of prices for copper, lead, tin, and zinc from the low figures of 1932 to 1937, as against the decline of the aluminium price, are reflected by the index numbers.

Outlook for Prices

Various developments in the world aluminium industry strongly indicate that the trend of prices for the metal will continue downward over an indeterminate period ahead. This is conditioned by the assumption that no major war will intervene. Substantial reductions in the selling price of aluminium have been made lately when the demaned was increasing. At the same time, the prices of other metals were being advanced. The latter is the usual procedure. That the price of aluminium has been lowered in a period of active trade is extraordinarily suggestive. It points to confidence for the future on the part of aluminium producers and also a determination to improve their competitive position against producers of other metals. The expectation is that the consumption of aluminium will continue to increase generally at a satisfactory rate. Besides, the average cost of producing the metal has been decreased appreciably over the last decade, due to betterments in metallurgical practice and larger output by individual companies.

Among other factors which have shaped the declining trend of prices for primary aluminium in late years the following have been the most important: (1) Cartel policy; (2) greatly-increased capacity for production together with new high quantities of annual output; (3) reduction of costs; (4) competition with other metals; and (5) the pressure of secondary aluminium on the markets. These items are discussed briefly below.

In respect of cartel policy the present international organisation of aluminium producers has followed the plan of gradually reducing prices. Most non-member producers have been influenced by action of the cartel. When the predecessor of the Alliance Aluminium Cie. was formed in 1926 the price of primary aluminium was £118 a ton. This was lowered several times in subsequent years, and in 1932 to £80. Thus the total reduction in about five years amounted to £38, or approximately 32%. (These prices are based on gold of former value.) In conjunction, the decline of prices in Germany and the United States over the period 1926 to 1938 may be remarked. The average price of primary aluminium in Germany was about 2·29 marks per kilogram in 1926, and 1·33 marks in 1938, the reduction being almost 42%. In the United States the average price was about 27 cents per pound in 1926, and 20 cents in 1938, the decline being nearly 26%.

During the last few years aluminium output of the leading producers has been increased impressively, and most works have been operated at capacity. The unit cost has decreased where it has been possible to utilise capacity more fully than previously. World output of aluminium rose to the former maximum of 282,100 metric tons in 1929, and fell to 141,700 tons in 1932. A new high record was attained in 1936 when outturn of the world was 365,700 tons. But another new maximum was recorded in 1937 when total output was 490,600 tons. Consumption of primary aluminium exceeded output substantially in the three-year period, 1935 to 1937, and stocks were correspondingly reduced. Furthermore, both output and consumption of secondary metal rose to new high levels.

World capacity for the production of primary aluminium has been greatly enlarged within the last decade. Total capacity in 1929 was approximately 300,000 metric tons, while in 1937 to 1938 it was about 550,000 tons. Accordingly, the increase was a little more than 45%. It is

expected (6) that new works with aggregate capacity of 250,000 ± tons may be ready for operation within the next two or three years. Moreover, large additional capacity has been projected for subsequent construction. The effect of such expansion will be generally bearish on prices if consumption cannot be raised in accordance or when a serious depression occurs.

The cost of producing aluminium has been appreciably decreased in the course of recent years owing to improvements in metallurgical practice. Larger and more efficient reduction cells have been installed in new works, and as replacement in old works. An outstanding development is the high-power cell with Söderberg continuous electrode. It is considerably more economical, especially as to consumption of electricity, than the old type with multiple anodes. Furthermore, the electrode cost with the former is much less than with the latter. Closed Söderberg cells are now generally favoured, and many have lately been put into operation at a number of works.

Lower prices for aluminium have promoted consumption, and strengthened the competitive situation of the industry. Reductions in the selling price have made aluminium more attractive and economical in both old and new fields of use in place of other metals. Also, the economic utility of aluminium is better than formerly on account of technical advances. In addition, developments are now being made in several directions which should further enhance the value of aluminium and permit its application for various new purposes. An important matter of recent origin is the forced use of domestic aluminium as a substitute for imported metals, especially copper and tin, in totalitarian countries. And, in order to encourage the more general use of aluminium in such countries, the selling price has been reduced.

Finally, the effect of secondary metal on the markets for primary aluminium is to be noted. As is known, scrap and secondary aluminium are employed widely in place of primary metal. The former materials are being recovered in increasing quantities, and they sell at lower prices than the latter. As more primary aluminium goes into consumption the actual and potential supply of scrap becomes greater. In these circumstances (and as in the case of other metals), more competition with scrap and secondary material is being encountered in the sale of primary aluminium. This situation has a depressing effect on prices for aluminium and manufactures in general.

Some Corrosion Problems Relating to Wrought Aluminium Alloys

THE necessity for careful temperature control during the solution heat treatment of Duralumin and the beneficial influence of a rapid rate of cooling after such heat treatment on the corrosion resistance of this material are now widely appreciated. There is evidence that advantage, from the point of view of improved resistance to corrosion, is also gained in the case of wrought Y alloy and, to a smaller extent, in the case of wrought aluminium alloy to Specification D.T.D. 206 by cooling comparatively quickly after solution heat treatment. In recent investigations, Sidery and Willstrop[1] observed that the best combination of corrosion resistance and tensile strength in wrought Y alloy was obtained by quenching the material in cold water after solution heat treatment and ageing for two hours at 100° C. Wrought aluminium alloys of the type represented by Specification D.T.D. 206 require an "elevated temperature" ageing treatment of the development of the optimum tensile strength in the material, but, in the fully heat treated condition, are usually found to be susceptible to intercrystalline corrosion. The ageing of the solution heat-treated sheet at 165 to 175° C. as comparing with ageing at ordinary temperature, increases the tendency of the material to corrode, irrespective of whether hot or cold water is used for quenching from the solution heat-treatment temperature. Quenching in cold water from the solution heat-treatment temperature, as opposed to quenching in boiling water, results in the attainment of slightly better tensile strength and improved corrosion resistance in the material, even when finally aged at elevated temperature.

The application to fully heat-treated and aged Duralumin of processes which necessitate re-heating the material may cause a serious reduction in its intrinsic corrosion resistance. Observations have shown that when reheated at temperatures above about 140° C., heat treated and aged Duralumin is liable to become very susceptible to intercrystalline corrosion, whereas reheating the material at temperatures up to about 125° C., whilst tending to increase its corrodibility as compared with that of material not reheated, does not induce this propensity towards intercrystalline corrosion. It is desirable therefore that in cases where stove-enamelling treatments or other processes involving reheating at elevated temperature have to be applied to Duralumin, a temperature of 125° C. should not be exceeded. It is noteworthy that the corrosion resistance of Duralumin which had been reheated within the temperature range 50 to 170° C. does not appear to be affected either adversely or beneficially by subsequent storage of the reheated material for 600 days at ordinary temperature.

Serious consequences from the point of view of resistance to corrosion have followed the application of cold forming operations to certain finally heat-treated and aged aluminium alloys. Mention is made of an extruded T section in an alloy covered by B.S.S. L 40 which had been subjected to cold deformation after final heat-treatment and ageing. This section, after being bent was subjected to the sea water spray test in the unprotected condition for a period of three weeks, developed a series of cracks which were observed to be intercrystalline. Similar cracking due to cold forming operations under unsuitable conditions has been observed in extruded material to Specification D.T.D. 363, an aluminium alloy which when heat-treated and aged, is capable of developing very high tensile strength. In this case the extrusion had been anodised after being formed and had been allowed to stand in the workshop for about two weeks at the end of which cracks were observed.

The results of corrosion tests have indicated that this tendency to crack can be considerably reduced, if not entirely removed, by carrying out all forming operations preferably on annealed material and then applying the requisite solution and ageing treatments or, alternatively, by performing the shaping operations on solution heat-treated material and then applying the final elevated temperature ageing treatment. It is usually observed that, under corrosive conditions with or without applied stress, high strength aluminium alloys requiring to be aged at elevated temperature for the development of their optimum tensile strength, are more resistant if exposed in the solution treated condition, i.e., without elevated temperature ageing treatment. It has been found, however, that under stress/corrosion conditions, alloys of the type corresponding to D.T.D. 363 are more resistant when exposed in the fully heat treated and aged condition than when exposed in the solution treated condition. Normally, heat-treated and aged Duralumin shows comparatively high resistance to failure under stress/corrosion conditions.

1 "Some Corrosion Problems Relating to Modern Aircraft" by A. T. Sidery and J. W. W. Willstrop. Advance Proof, Royal Aeronautical Society.

Progress in the Application of Aluminium

By William Ashcroft

The outstanding property of aluminium is its lightness, a property shared with most of its alloys. Almost as important is its resistance to corrosion. Other properties include its electrical conductivity and ductility. It is soft and weak, and for most commercial purposes it must either be alloyed with other metals, or cold-worked, or both, and some of the alloys may also be heat-treated. Attention is directed more particularly to developments in its use.

By courtesy of Messrs. Short Bros. Ltd.

One of the outstanding achievements of 1938 was the introduction of the "Empire" flying boats. Many tons of "Alclad" sheet were used in the construction of each machine.

THE first step towards the production of aluminium on a practical scale was made by Oerstedt in 1825, when he obtained aluminium chloride. Two years later the metal was isolated by Wöhler, but the small amount produced was much contaminated with other substances, and it was not until 1845 that he was able to produce purer metal in quantities sufficient to carry out physical tests. But the metal remained a laboratory curiosity until 1854 when Clair Deville, a French chemist, devised two methods for producing aluminium, one of which remained for many years the sole means of producing the metal on a commercial scale. The materials used by Deville were aluminium chloride, common salt, fluorspar and a form of alumina, or cryolite, a compound of aluminium and sodium chloride from Greenland. The adoption of this process greatly reduced the price of the metal, and Deville hoped that this fact would facilitate its commercial use, but progress in its application was very slow and discouraging, until 1886, when Hall and Héroult, working independently, discovered the electro-metallurgical process of reduction, and gave a new impetus to the development of aluminium which is now applied in such wide and varied purposes that to-day, in point of tonnage, it ranks as fifth in the world's metals.

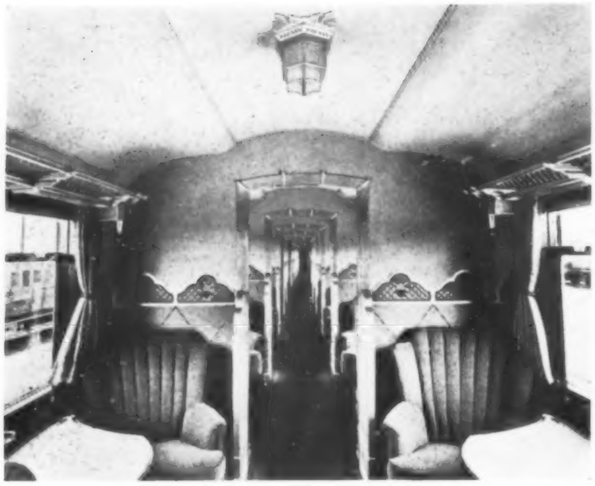
The method developed by Hall and Héroult consists in passing an electric current through a bath composed of alumina (Al_2O_3) and molten cryolite. The method involves the electrolysis of a molten electrolyte in a furnace. The molten cryolite, at the bottom of the furnace and upon which alumina is charged, forms the cathode, in which reduced aluminium from the charge is deposited, and the anode consists of rod, or rods, of graphite or carbon, which is consumed by the oxygen given off from the charge. Although many improvements have been made in the equipment and in the details of the process since its discovery, in principle, the process used to-day is substantially as invented by Hall and by Héroult within a few weeks of each other.

Although this discovery provided facilities for the production of aluminium at a much lower cost than by the purely chemical processes of manufacture, the application of the metal in the various industries was very slow, and by 1905 the world production of aluminium had only reached about 10,000 tons. It was regarded as a new metal about which little was known, and the introduction of a new metal to common usage will always be difficult. The relatively low strength of the metal probably helped in retarding its progress, but the use of copper as an alloying element to increase its strength, assisted in the gradual application of the metal, particularly in the manufacture of kitchen utensils, but the discovery of Wilm, in 1911, after many years of experimentation, that certain aluminium alloys could be given materially improved physical properties by heat-treatment at a definite temperature followed by quenching in water, indicated the potential value of aluminium for wider applications. The increased strength obtained by the heat-treatment of an aluminium-copper alloy in his earlier experiments was not sufficient for his purpose, but subsequently he discovered that the addition of a small percentage of magnesium caused an additional change in properties, which took place at room temperature a few days following the heat-treatment, and resulted in a decided increase in tensile strength without any reduction in ductility.

The development of the composition and the technique of production and heat-treatment presented many initial difficulties, but the alloy was eventually produced commercially by the Durener Metallwerke, who gave the alloy

"Ensign" class passenger 'plane constructed largely of "Alclad" aluminium alloy.

By courtesy of Sir W. G. Armstrong Whitworth Aircraft Co. Ltd.



By courtesy of Sir Nigel Gresley, Chief Mechanical Engineer, L.N.E.R.

Interior of 1st class coach on the L.N.E.R. "Coronation Express." Aluminium alloys are used for interior decorative equipment.

the name Duralumin. From then onwards, particularly since the war, intensive research and experimentation, in practically all industrialised countries, have contributed to the development of aluminium alloys. In addition to the original Duralumin, there are now many heat-treatable alloys which, following suitable heat-treatment and ageing, yield a range of tensile strengths up to nearly 40 tons per sq. in.; these, together with a wide range of non-heat-treatable alloys which have been developed, are now available in convenient marketable forms.

It is not proposed to discuss the development of the principal aluminium alloys here, but a brief reference to the alloying elements used may be of interest. The commercial grade of aluminium is specified as a minimum of 98% purity, but in modern conditions it is rarely below 99% purity. Aluminium is hardened by work, and in this grade sheet is obtainable in five tempers from soft to hard, each covering a variety of operations for which this material is used. In addition to the commercial grade, there are available a 99·5% minimum grade, which is generally preferred for chemical plant, and higher purities up to 99·8% minimum for special purposes. Electrically-refined aluminium is also in commercial production which has been standardised at 99·99% purity.

Though very ductile, aluminium is relatively soft and weak, and, in order to obtain the strength and hardness required for most commercial purposes, it must either be alloyed with other metals, or cold-worked, or both, and some of the alloys may also be heat-treated. In the wrought medium-strength alloys, which, in the appropriate temper, have a combination of useful properties without the complication of heat-treatment, the aluminium-manganese, aluminium-silicon and aluminium-magnesium alloys are general, the latter usually having minor additions of manganese. All these have one property in common, they can be considered to be equal to pure aluminium in respect of corrosion resistance, while the magnesium alloy has superior resistance to marine corrosion. The mechanical properties, however, vary and provide a useful range for general purposes.

The heat-treatable wrought alloys all bear some relationship with the original Duralumin, and in addition to this alloy include "Y" alloy, the RR series as typical of this type. These are more complex alloys and contain up to about 4% of copper, up to 3% magnesium, with or without smaller contents of silicon, manganese, nickel, iron, titanium, etc. Having fairly good forming properties and a weight only about one-third that of steel, this type of alloy has opened up new and extensive structural uses for aluminium wherever the saving of weight of the structure is of sufficient importance to justify its cost.

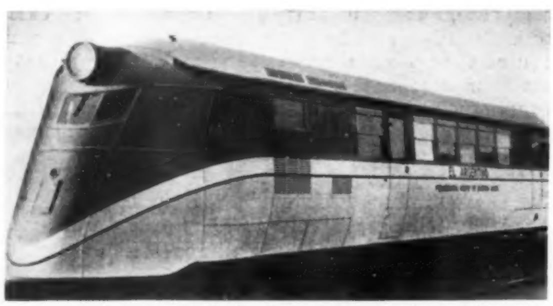
The casting alloys may also be roughly divided into those capable of heat-treatment, and those not heat-treatable. The latter supply the majority of castings for general engineering parts and comprise aluminium-copper, aluminium-zinc-copper, aluminium-silicon, aluminium-magnesium-manganese, aluminium-copper-nickel-magnesium as typical alloys. The heat-treatable alloys are more complex and contain additions similar to those for the high-strength wrought alloys.

Concurrent with the active and intensive research on aluminium and its alloys technological progress has broadened their applications, apart from the development of new alloys, methods of fabricating have advanced, welding and riveting of structures presented problems which are now substantially overcome; and the processes associated with heat-treatment, and the production of surface finishes have made great progress. As a result, the application of aluminium and its alloys has been extended to purposes for which they were previously uneconomic in competition with other metals and materials.

Aircraft

Undoubtedly the development of the aircraft industry gave a great impetus to the aluminium industry. In addition to low specific gravity and relatively high strength, this metal and its alloys have excellent ductility and malleability, high thermal and electrical conductivity, remarkable resistance to corrosion; it is not surprising, therefore, that they have contributed, and are contributing to an increasing extent, in the rapid development of aerial transport.

For the use of castings as components performing important duty, such that failure of a particular casting might imperil the entire aircraft; it will be appreciated that very high standards of quality are necessary. The applications of castings in aircraft are becoming increasingly numerous, and the duties to be performed more and more vital. Aluminium alloy castings of several different types are used for aircraft components. The heat-treatable casting alloys form a very important group to-day, and this group can be sub-divided into casting alloys heat-treated at low temperature only, and casting alloys solution heat-treated and then given low-temperature treatment. The low-temperature heat-treatment lowers the elongation value without rendering the castings unduly brittle, but usually increases the ultimate stress slightly and the proof stress appreciably. An important practical advantage lies in the fact that internal casting stresses are released to an



By courtesy of The Birmingham Railway Carriage and Wagon Co.

The weight of this railcar has been reduced by more than half that of an ordinary railway carriage of similar dimensions by the use of modern constructional methods and aluminium alloys.

appreciable extent, and danger of future distortion is much reduced. Double heat-treatment—that is, solution heat-treatment followed by ageing at elevated temperature—is applied to a number of important alloys principally for the development of high strength properties. This frequently entails precautions against distortion, especially for the larger castings. The high silicon type of aluminium casting alloy is used for aircraft parts in which high intrinsic resistance to corrosion is required.

In this field wrought alloys of the Duralumin type are the most important high strength single heat-treated alloys. As with other materials, experience and the industrial application of the results of research have yielded an improved product. In recent years there have been many developments in this field of light alloy technology. The alloys Duralumin G and Hiduminium 72 are alloys of the single-solution heat-treatment type, which develop high mechanical properties on ageing at room temperature. They have high ultimate and 0·1% tensile proof stresses, good working properties, and a high resistance to corrosion. The improved mechanical properties, compared with Duralumin, are obtained by very slightly increased amounts of alloying elements, notably magnesium, and suitable control of the other added elements.

The double heat-treatment type of improved Duralumin alloy has found extensive use in modern aircraft. Here the optimum mechanical properties are obtained by applying first a solution heat-treatment and then an ageing treatment at raised temperature, say, 15 hours at 165° C. The ultimate stress is usually raised slightly, and the 0·1% tensile proof stress appreciably, the ductility being reduced slightly. The corrosion properties are affected adversely, notably as regards resistance to the inter-crystalline type of corrosion. The alloys are capable of being used satisfactorily if suitable protective treatments and coatings are applied. The aluminium-clad material is outstanding in that respect, the resistance to corrosion and to mechanical deterioration being much increased by the aluminium coating.

Mention should be made of a new high strength wrought aluminium alloy of recent origin. This alloy contains 4 to 6% zinc, 2 to 4% magnesium, 1·5 to 3·0% copper, up to 1% of nickel, and small amounts of other elements. At present the alloy is being supplied in the form of extrusions, which, after an appropriate double heat-treatment have strength properties of the order of 27 to 33 tons per sq. in. tensile, and 33 to 38 tons per sq. in. ultimate tensile strength, with 10 to 16% elongation. The specific gravity is about 2·8. The alloy in this condition appears to possess good resistance to corrosion, as judged by laboratory tests. The results of practical experience will be awaited with interest.

Road and Rail Transport

The properties that give aluminium and its alloys advantages for aircraft purposes are also applicable to vehicles for road or rail transport. Sheet and sections for

By courtesy of Messrs. E. G. Brown Ltd.

Motor-car body constructed in aluminium.

bodywork and panelling, sand castings and gravity die-castings for various fitments, forgings for parts to withstand high service conditions and pressure die-castings for many small fittings in these industries absorb a steady heavy tonnage. In heavy road transport vehicles the use of aluminium pistons, crankcases, gearcases, radiators, etc.,

By courtesy of The Northern Aluminium Co. Ltd.

Aluminium alloy internal combustion engine pistons.

have become general, while aluminium cylinder heads are increasingly used. The present-day possibilities of using suitable extruded sections opens up new potentialities in regard to the construction of heavy-duty vehicle bodies, since they not only reduce the cost of vehicle construction, a factor which in the past has weighed rather heavily against the wider adoption of light alloys, but they also simplify the construction and facilitate assembly.

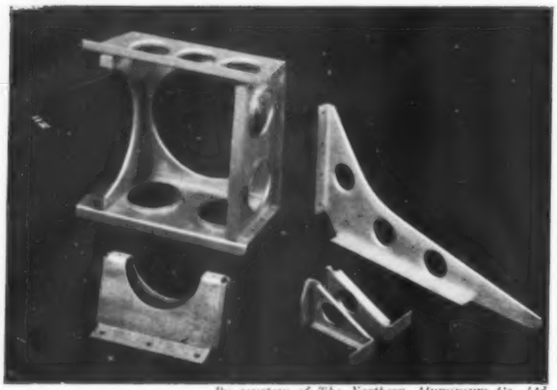
In public vehicles, whether on road or rail, aluminium is being used for panelling, structural supports, seats, roofing and window fittings. In one city 50 aluminium cars are being put into service. The extensive use of aluminium alloys permits of a radical weight reduction. There are very few countries which do not yet take advantage of the developments in the use of aluminium alloys in the construction of rolling-stock. Railcars and trailers are now operating in which a considerable saving in weight has been effected. The initial cost of making greater use of aluminium is higher, but experience has demonstrated that increased pay load, various economies effected in construction, and the high scrap value of the metal contributing to eventual replacement cost, prove the economy of aluminium construction, even when comparative figures are taken over a relatively short time.

Aluminium alloy containers have long been in successful use for the transport of foodstuffs, not only by reason of savings on freight, but also because any possible contamination of foodstuffs is prevented by their use. Tanks and containers of aluminium are also of great value for the transport of many chemicals by reason of the chemical inactivity of the metal. A recent development is a new 1,500-gallon, three-compartment aluminium tank-wagon built for the Anglo-Dutch Petroleum Co. (Eastern), Ltd. Another is the use of aluminium carboys for the transport of chemical products, similar to the glass-carboy type. This new carboy is unbreakable and, by comparison with a glass carboy and wood protective case which are 60 lb. in weight, the light-metal container weighs only 10 lb.

The advantages arising from weight reduction by the greater use of aluminium in motor-car construction is gradually being appreciated. Reduced fuel consumption together with better acceleration and hill-climbing, and reduced tyre wear are favourable factors resulting from weight reduction, and in addition to many engine details and car fittings, more attention is being given to the use of aluminium for bodywork. The maximum use of aluminium is also being made in many British motor-cycles, and although in pedal-cycles in this country the use of light metals is restricted to accessories, cycles with aluminium-alloy frames are manufactured in France.

Shipbuilding

The use of aluminium in marine construction is more widespread than is generally appreciated. The primary reason for using light alloys in shipbuilding is to save weight, but the advantage they offer in reducing the fire



By courtesy of The Northern Aluminium Co. Ltd.

Aircraft parts pressed from high strength aluminium alloys.

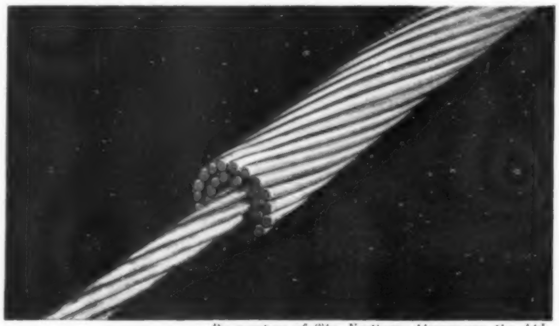
risk, when used in place of wood, should not be overlooked. They also bring about reduction in stress by the reduction in weight of moving parts and the good finish and high resistance to corrosion of suitable alloys make them particularly suited for internal fittings. The lighter weight reduces running costs for a similar speed, and gives a slight increase in stability due to lighter superstructure and other fittings high in the ship. A ship's superstructure is continually exposed to sea spray, and an alloy must be used which has corrosion-resistance qualities similar to pure aluminium, and as alloys of this type have been available for many years and have successfully withstood the conditions encountered in marine applications, it is not surprising that the tendency to make greater use of aluminium in the superstructure of passenger vessels is growing. The funnels of one vessel are constructed in aluminium, and it is probable that in the near future its use will be greatly extended when it will be possible to increase the height of the superstructure and the capacity of the vessel without reducing its stability.

There is room for further weight saving in the engine of a vessel, although much progress in this direction has been effected. Thus, for instance, such parts as gear casings engine bedplates, crankcases, floor-plates, lubricating pumps, etc. are made in aluminium alloys, while the pistons for Diesel engines are also being supplied in large quantities. A considerable amount of aluminium is used for searchlight parts, port-holes, grilles for lift enclosures, lockers, partitions, cabin decorations, etc., but it should be remembered that aluminium has been used as a decorative material in passenger vessels for many years. The old *Mauretania*, for instance, built in 1907, had some excellent examples of aluminium fittings and grilles installed. Portable boats and ships' lifeboats have long been made from aluminium and, in view of the service they give, the demand for them is increasing. A recent substantial application is in New York's new ferry boat, the *Gold Star Mother* which has about 30 tons of aluminium in her construction. The two sister-ships of this boat, the *Mary Murray* and the *Miss New York*, will have a similar amount when completed.

It should be remembered, however, that the extent to which aluminium can be used in the mercantile marine is governed largely by its initial cost. Although there are many advantages associated with its use they must be considered in relation to this cost, and when it is realised that the saving of each ton by substituting aluminium alloys for steel will cost about £150, it will be appreciated that the more general use of light metals in cargo vessels is not likely to make much progress until a reduction can be effected in the cost of aluminium. In some instances, however, as in the case of ship's lifeboats, the cost of construction in aluminium is much reduced, with the result that there is little difference in the overall cost in comparison with the usual type of lifeboat of similar capacity.

In the construction of war vessels the position is very different, the saving in weight is not merely an advantage, it has become a necessity since the introduction of naval treaties which limit the displacement of various classes of vessels. Thus in the Navy more extensive use is made of light alloys. In the Kent class, for instance, a saving of weight of nearly 200 tons was thereby effected, and the experience gained in these vessels has been utilised in later ships, and full advantage taken of the development in the material and improvements in its mechanical and anti-corrosive qualities.

Aluminium sheet is used for cabin linings, kit lockers, bread lockers, coat cupboards, food cupboards, bins, shelves, racks, dresses, drawers, etc., in messes, pantries, kitchens, galleys, and storerooms ; with satisfactory results. Non-watertight parts of ventilation trunking not subject to gunblast and not immediately adjacent to a fan are made of sheet aluminium. All side scuttles and deadlights, including those subjected to gunblast, are made of aluminium-silicon alloy, as are all valves, filters and hand-wheels in the oil-fuel filtering system (except those exposed to the action of bilge water), ventilation valves and various tally-plates. Pistons of internal-combustion engines are of "Y" alloy, whilst a number of engine parts, such as gear-case covers, inspection covers, cleaning doors, pressure-gauge cases, etc., are of aluminium-silicon alloy. Aluminium alloy has been extensively adopted for electrical work, including parts of electric-light fittings, switches, fuse-boxes, distribution, section and junction boxes, small end frames and other parts of electric motors.



By courtesy of The Northern Aluminium Co. Ltd.

Section of steel-cored aluminium cable showing the outer aluminium cover used for electrical transmission.

By courtesy of The Morgan Crucible Co. Ltd.

Crucibles in fused alumina.

Another extensive application is in the form of foil for heat insulation, aluminium sheets are widely superseding asbestos, cork, etc., for lagging purposes, owing mainly to its extreme lightness. Aluminium paint has been introduced as a standard Service paint after exhaustive trials, and considerable weight is saved by its adoption.

Food and Chemical Industries

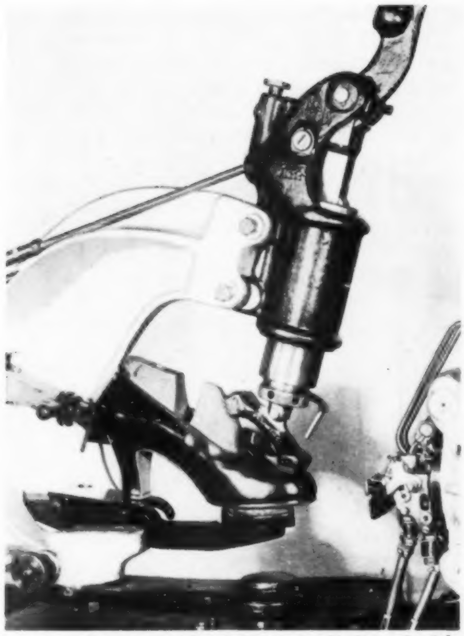
From the early days the metal has proved attractive for cooking utensils, and its popularity for this purpose has made increasing demands on producers. Although the bulk of this industry is produced from sheet, the greater life of cast utensils has opened considerable possibilities, especially when die cast. In addition to cooking utensils,

however, the application of aluminium to the manufacture of hospital utensils has been very marked. In both these applications the anodic oxidation process has materially assisted.

The same properties of this metal have led to its general application in the food industries. This is supported by the popularity of aluminium, after about thirty years' employment for domestic cooking utensils, that no harm results from eating foods prepared or stored in aluminium vessels. Apart from its use in a wider range of equipment, it is noteworthy that aluminium trays have largely replaced wood, especially in the confectionery industry. The reason is the improved hygienic value of the metal. Not only bacteria, but the lava of the chocolate moth has been found to breed in a prolific manner in the crevices of the wood trays formerly used, and the cleanliness of aluminium has increased its use for this purpose.

By courtesy of Messrs. Ransome and Rapier Ltd.

Excavator bucket with a capacity of 11 cubic yards constructed from aluminium alloys. This bucket will lift approximately 2 cubic yards more per stroke than a steel bucket of similar weight.



By courtesy of British United Shoe Machinery Co. Ltd.

An automatic edge-setting machine incorporating aluminium in its construction.

The hygienic and other advantages of aluminium have led to its application for equipment and components in dairies, and dairy churns are now frequently made in this metal. In many instances it is displacing tinplate for milk cans which are distributed throughout the country. Not only has the relatively short life of the tinned article led to the introduction of aluminium, but experiments have tended to prove its superiority to the latter metal from the hygienic standpoint, and many of the important dairies, having investigated its possibilities, are now making greater use of the metal. Various kinds of bottles are being turned out in seamless aluminium, not only for milk and beer, but also for essences, essential oils, perfumes and chemicals. Such chemicals as formaldehyde and acetic acid are regularly packed in aluminium drums.

Aluminium possesses a combination of chemical and physical properties which fit it admirably for contact with many chemicals. Higher efficiency, high quality of product, and lower operating or transportation costs are among the advantages. It is interesting also to note that the aluminium container keeps its contents cool when exposed to strong sunlight, because the reflecting power of the bright metal is greater than its absorbing capacity. Many materials are substantially inert towards aluminium, among which may be included distilled water, steam, hydrogen peroxide, concentrated nitric acid, sulphur, organic-sulphur compounds, anhydrous-sulphur dioxide, acetic acid, fruit acids, fatty acids, sodium soap, ammonia, aldehydes, turpentine, alcohol, varnish, rosin, many dye solutions, in addition to milk and beer, which can be handled advantageously in aluminium equipment. It should be remembered, however, that as no one metal or material is entirely resistant to all conditions to which it may be subjected, the suitability of aluminium for each new application should be very carefully determined.

In applications requiring the use of relatively thin sheet, under corrosive conditions, where maintenance of the original mechanical properties is required, a strong sheet may have a surface coating of corrosion-resistant aluminium, or an alloy whose solution potential is such that it will electrolytically protect the underlying metal. The core metal may be a strong aluminium alloy, such as is used in aircraft, or a common alloy may be used according to the purpose for which it is required, but in each case surface protection is afforded by means of a thin aluminium coating, as in the case of Alclad sheet. Surface protection can also be obtained by spraying the surface with aluminium, by electrodeposition, or by means of aluminium paint, depending upon the service conditions.

Other Industries.

The light-weight and corrosion-resistance qualities of aluminium and some of its alloys render them particularly suitable for the textile industry, and it is interesting to note that the rayon industry leans heavily towards their use in its equipment, as aluminium has proved very satisfactory in resisting the attack of acid and alkaline solutions used. Large tanks and other components in aluminium are now conspicuous in the plant and machinery used in this industry. Among the smaller pieces of equipment are the perforated bobbins on which the viscose silk is wound for washing purposes.

Aluminium is a material which also meets many requirements of laundry equipment. It withstands the chemical action of the solutions used in the laundry, is non-staining owing to the fact that its salts are colourless, and the metal itself has an attractive appearance without necessitating plating. It has long been known that, although concentrated solutions of soda will attack aluminium, the metal is resistant to dilute solutions up to 0·3% (considerably stronger than the solutions normally used in the laundry), and that the presence of soap results in a protective film which still further inhibits the action of soda. Aluminium alloy washing machines have been in use in London laundries for several years on all classes of work and for all purposes, including boiling and bleaching, and have given every satisfaction. The machines have been extremely easy to keep clean, and there has been no marking-off on to the clothes.

In the manufacture of shoe-machinery aluminium has been applied with complete success. It is used mainly in the form of castings in ordinary commercially-pure and alloyed forms, in some instances, because of its lightness, and in other because of its resistance to corrosion by various

inks, stains and adhesives used in shoemaking. In one machine, which is used for grading and cutting uppers and soles of all styles and shapes, a large overhanging arm and a squared grid carrying the model pattern are cast in "Y" alloy. In a clicking press a 13-in. swing beam is often an aluminium-alloy casting with the object of making the operator's work less fatiguing. Another machine, an automatic edge-setting machine, incorporates aluminium in its construction. The casting of the "jack" which carries the shoe is of ordinary commercial aluminium, but the oscillating head mechanism, shown on the right in the accompanying illustration—which is very delicately balanced to enable it to follow the contours of the edge of the sole accurately under hydraulic control—is of aluminium alloy, heat-treated.

An interesting machine designed for attaching soles, carries a number of "box" castings, each of which carries a pad on which the shoe and sole are pressed together, while the adhesive which secures the sole is setting. These box castings are of aluminium which is used not so much because of its lightness, but because of its resistance to corrosion. In this machine a special "finger" mechanism for gripping the sole is also built up from aluminium castings, while eight large die-cast aluminium brackets, secured to the centre column of the machine, are used to carry the pad boxes.

Many thousands of tons of aluminium are used in the production of wire and cable for the electrical industry. Since the first aluminium transmission line was erected in America, about 1898, there has been a growing application for aluminium, while aluminium busbars in electric power-stations is another direction in which much progress has been made.

Although it is rightly claimed that aluminium and its alloys are the products of the laboratory, because it is undoubtedly true that progress in this development is due to the valuable research and experimental work successfully carried out, an interesting fact in connection with these developments is the rapid manner in which they have been assimilated by many industries, and the results applied to meet new and existing conditions of service.

Architectural & Decorative Applications

THE natural finish and ease of working of aluminium make it a very suitable metal for architectural purposes, and it is now used in a wide variety of such applications. Its silvery appearance and freedom from corrosion have resulted in its increasing use for balustrades, panels, handrails, gates, grilles, columns, lamps, and much ornamental work. In addition to its capability for receiving refined treatments comparable with those given to silver, there are the many attractive finishes in a large range of colours and tones obtainable by anodising, thus making it suitable for harmonising with or contrasting with any decorative scheme.

Further, there are the varying degrees and types of surfaces resulting from sand blasting, scratch brushing, frosting—by dipping in caustic soda and nitric acid—and the scope of its application for architectural purposes is greatly increased by the availability of a very wide range of extruded sections.

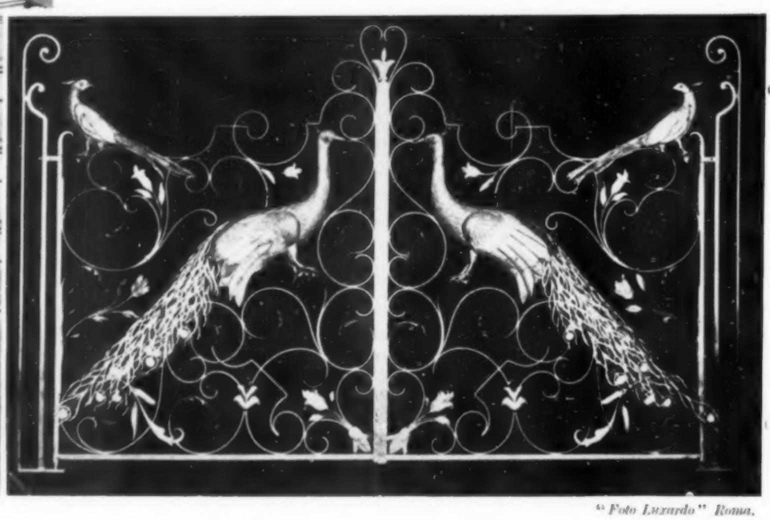
It is also an excellent medium for hand working, enabling the skill of the craftsman to be exploited to fullest advantage. In some such examples the metal has been chiselled delicately, twisted and hammered into intricate shapes, these then being welded one to another, or to the main component of the design. Acanthus light brackets in floral design, gates with ornamental horses, and gates with scrolls, peacocks and pheasants are among such hand-worked examples of outstanding beauty of effect.

It is thus apparent that aluminium can be regarded as a serious and desirable addition to the range of metals—such as bronze, iron and copper—which can be used for decorative and architectural work. Also, as larger extruded sections are now available, the use and scope of aluminium for structural work has been considerably extended. Many excellent examples of such application are to be seen, including large area panelling, shop fittings, decorative additions, and fascias.

The facia and doors of the Italian State Railway's Offices, executed in anodised Aluminium by H. N. Barnes Ltd.

By Courtesy of Northern Aluminium Co., Ltd.

Aluminium gate with peacocks and pheasants, it is $47\frac{1}{4}$ ins. high and $74\frac{3}{4}$ ins. wide.



"Foto Luxardo" Roma.

The British Industries Fair

Great interest continues to be shown in the various sections of this Empire Fair, and in regard to the area occupied and the number of firms exhibiting this year, the exhibition will at least equal that of any preceding year in popularity and interest. In this review attention is directed more particularly to the metallurgical features of the Castle Bromwich Section.

ORGANISED by the Department of Overseas Trade, this Fair is held at Olympia, Earls Court and Castle Bromwich, simultaneously. It is entirely a national effort to display the wide resources of the British Empire and to provide facilities for presenting to the world's buyers the developments of British industry. Although the area occupied and the number of exhibitors are not quite so large as last year, largely due to the pressure on the activities of many firms in other directions, visitors will find each section very comprehensive. At Olympia, for instance, there are about 900 exhibitors, whose stands occupy about 274,000 sq. ft. and concerned mainly with manufactured goods ; at Earls Court, which is concerned primarily with textiles, the number of exhibitors is about 415,who occupy about 244,000 sq. ft. ; while at Castle Bromwich, which is mainly concerned with engineering and hardware, there are about 850 exhibitors occupying about 300,000 sq. ft.

A four-piece tea-set and tray in "Staybrite" steel

Formed with the object of becoming the centre from which United Kingdom manufacturers and traders could obtain reliable information of a commercial nature concerning any overseas market, the Department of Overseas Trade is served by a network of representatives throughout the world, who maintain a constant supply of information to the home centre, and provide local assistance in the promotion of United Kingdom trade. The Department has been responsible for this Fair since it was first held in 1915 and the primary object is the assembling before the largest number of potential buyers, both home and overseas, the greatest possible concentration of British manufactures.

In the engineering section at Castle Bromwich it will be noted that, although many firms are concentrating on the vital defence needs of the country, the opening of the Fair, on February 20, will show there is no lack of eagerness to seek new customers and new markets, at home and overseas. After all, business confidence is the best contribution and solution to many of the world's problems, and the facilities afforded by the Fair of bringing together potential buyers and manufacturers is of great assistance in effecting increased confidence.

Apart from its main function, however, the Fair provides a useful guide to progress and provides an incentive to manufacturers to display products which demonstrate advances in science and the arts. Incidentally, the potential buyer has the opportunity of making comparisons and of seeing the extent of progress in the directions which are of direct interest to him. Exhibitors vie with each other in presenting their products in the most attractive form.

It will be appreciated that while this Fair, as with previous ones, constitutes a new drive for world trade, it represents the scientific and technical skill which has been developed to ensure that the products of British industry continue to occupy the high position which has always been attained by them. Visitors may be assured that in regard to scope, quality and workmanship, these products are not exceeded by any other country, and their cost, having regard to reliable service, will compare favourably with that of similar products made elsewhere. The range of products displayed at Castle Bromwich is so comprehensive that it is possible to review only some of the metallurgical features here in connection with the engineering section, the primary object being to assist readers with limited time at their disposal when they visit the Fair, and, at the same time, to direct the attention of those unable to go to some outstanding features connected with ferrous and non-ferrous metals, plant and equipment.

Metallurgical Developments : Iron and Steel

Although the iron and steel industry has been faced with difficulties since the last Fair, as a result of falling trade, the various firms have not permitted the recession to interfere with their development schemes. The industry has continued to provide increasing production facilities, and some noteworthy installations have been put into operation, or are approaching that stage. In addition to plant installations and improvements, however, there has been unceasing effort in improving practice to ensure a better quality of the particular grade produced. This applies especially to the low-cost, low-alloy steels in which improved knowledge of the effects of alloying elements has resulted in the application of high tensile steels for a wider range of purposes. Many of these low-alloy steels cost little more than carbon steels of similar carbon content, but their strength properties are very superior without sacrifice of machinability. These low-alloy steels are not new, but the trend of metallurgical development has been directed not only to high tensile strength, but to increased toughness, and in some cases possessing greater resistance to corrosion than do carbon steels. Attention has also been directed to the improvement of the welding and fabricating properties of these steels to increase their use for structural purposes where their greater strength is very important.

Considerable progress has also been made in the improvement of steels for use at high pressures and temperatures ; in this field the efforts are directed to the

A group of Firth-Vickers heat-resisting steel hardening pots manufactured by F. Atkinson (Nottingham) Ltd.

development of steels which possess suitable physical properties, but, in addition, have stable creep-resistance. The higher alloy steels developed for corrosion-resistance or heat-resistance purposes have also entailed much work during the year with a view to easier manipulation, so that their field of usefulness can be increased. The majority of the large firms engaged in the production of steel maintain research laboratories whose staffs are engaged wholly in devising means for improving the quality of a particular grade of steel or in developing new or modified alloys with improved properties, and invariably the services of these laboratories are available to prospective buyers. Technical experts will be at the various stands containing exhibits from steel plants, and will discuss the steel problems of visitors and help in every possible way to ensure the use of a steel for a particular purpose which will be both reliable and serviceable.

Continual development has increased the range of steels to such an extent that the services of an expert are invaluable in the selection of a steel for a particular purpose, since the cost and performance are now such vital factors. At the Birmingham section of the Fair observant visitors have the opportunity of making comparisons and obtaining information regarding their requirements with comparative ease. They will see a range of steels from the soft steels from deep drawing and stamping to those possessing tensile properties up to about 150 tons per sq. in., including the corrosion- and heat-resisting steels having high and low coefficients of expansion, magnetic and non-magnetic steels, tool steels and a large number of branded steels, some of which have become so well known that they represent a type of steel.

Improvement in the plant and equipment has resulted in the production of sheet and strip possessing a superior finish ; the same will be noted in ground bar which is now obtainable to very fine limits ; in all sections of the semi-finished products visitors will appreciate the general improvement in production technique.

The heavy side of the manufactures of Thos. Firth and John Brown, Ltd., will be represented by die-blocks ; a range of castings as used in the mining, quarrying and associated industries ; dredger buckets and spares ; whilst other examples of a general character will include various applications of nitralloy steel noted for its extreme hardness, and used for parts subject to hard wear. Other exhibits will be tyres, axles and springs.

Occupying the same stand as last year, the United Steel Companies, Ltd., feature stainless steel in the construction of the stand. The outside walls and doors of the lounge consist of satin-finished stainless steel sheet, and the six display counters are surrounded by bold strips of stainless steel. The whole stand is dominated by a tower bearing the United Steel Companies' emblem also fabricated in stainless steel. This material also figures in the decoration of the interior of the lounge.

It is not possible to display within the confines of such a stand the extensive range of steel and allied products produced by the United Steel Companies, Ltd., and, consequently, the inside walls of the lounge carry displays of photographic montages depicting outstanding examples of the utilisation of many of the company's iron and steel products in the spheres of structural railway and ship-building, automobile, aeronautical and general engineering. The main activities of the various firms in this organisation will be shown by many exhibits. Thus, in railway materials Appleby-Frodingham Steel Company, Ltd. display boiler-plates, carriage-frame girders, locomotive-frame slabs, etc. ; Samuel Fox and Co., Ltd., exhibit special alloy steels for connecting rods, coupling rods, staybolts and drawgear ; Steel, Peech and Tozer exhibit wheels, discs, tyres, axles, cranks and forgings ; while Workington Iron and Steel Company show acid Bessemer steel rails, sleepers and chairs.

Among the building materials visitors will be especially interested in the steel air-raid shelter by the Appleby-Frodingham Steel Company. Similar shelters can be supplied in a variety of dimensions to suit particular requirements. In addition this section includes joists, sections, plates and piling of the Appleby-Frodingham Company, and Stribar made by the United Strip and Bar Mills. A complete range of electric and special alloy steels is produced by Messrs. Samuel Fox and Co., Ltd., to meet the special requirements of the automobile and aeronautical industries. Samples of "Phoenix" rapid-machining steel will also be shown. This steel can be machined at the highest speeds of modern lathes and yet possesses high physical properties ; it can be drop-forged and case-hardened like ordinary mild steel. Of considerable interest are the special foundry irons produced by the Workington Iron and Steel Company ; they are chill cast and add to the quality of the West Coast hæmatite irons.

A complete range of Firth-Vickers corrosion and heat-resisting steels—" Staybrite " steel and Firth stainless steel—will be on view. The former is of the austenitic type, and embraces a wide range of steels for different purposes, and to various analysis. Its application has been so widely extended that it is now used extensively in all industries where cleanliness and hygiene coupled with strength and immunity from corrosion are essential. Firth stainless steel is largely used for cutlery. The display will include " Staybrite " and stainless-steel bars of various sizes ; " Staybrite " steel sheets of different finishes ; forgings ; castings ; cold-rolled strip and drop-stampings, whilst other forms of semi-fabricated materials including wire ; wire mesh ; nuts ; bolts ; rivets ; screws

Parts in Phœnix rapid-machining steel for electrical, general engineering and the motor trades

as supplied to Air Ministry specifications and for industrial purposes generally.

A further range of domestic articles, typical of many uses to which this metal is being applied will also be in evidence. New designs will be displayed. The feature of this steel for domestic purposes is its bright, pleasing appearance and the fact that it will retain this finish indefinitely. It requires no polishing, but only an occasional wipe over to retain its original lustre. It has been awarded the certificate of the Institute of Hygiene. Among new features to be displayed are an all-" Staybrite " steel dish-washing machine, as used by the leading hotels, cafés, restaurants, steamships, hospitals, etc., and a " Vel-Spa " water softener.

With the continually-growing demand for rolled-steel strip much interest will be shown in the exhibits of this useful semi-finished product, and of these the display of Messrs. Arthur Lee and Sons, Ltd. will attract attention. Representative production samples of hot- and cold-rolled steel strip and stainless-steel strip will be on view. A new hot mill has been installed by this firm embodying three separate units and with re-heating furnaces which enable the slabs and billets to be delivered in a uniform and correctly-heated condition, strip is being produced from one to 16 in. wide down to the thinnest gauges. The resultant material is in a physical condition most suitable for pressing and drawing operations without further heat-treatment. Special attention is given to surface condition and, after pickling, a close and smooth skin is obtained which, in addition to facilitating presswork operations, has a very important influence on the appearance of the finished product.

One of the stock departments of Messrs. Arthur Lee & Sons, Ltd.

The obvious advantages of bright finish, accuracy and reliability are constantly enlarging the usefulness of cold-rolled steel strip. It is admirably adapted for mechanical fabrication involving stamping, forming, bending, drawing and rolling, and in many cases has replaced more expensive methods of production. For this reason an investigation into the quality of strip now available in comparison with that of a few years ago would be worth while.

Pipes and Tubes

The increasing use of pipes and tubes in various sizes and types has resulted in production developments to meet more exacting conditions of service. Many displays will feature products resulting from these improvements. Stewarts and Lloyds, for instance, who manufacture steel pipes ranging in size from ⅛-in. to 72-in. diameter, will have a comprehensive display embracing tubes and fittings in gas, water and steam qualities; steel pipes for water, sewage and air mains; tubes and accessories for high-pressure steam power plant, and also for low-power installations; oil country tubular goods; colliery tubular equipment; boiler tubes, etc. Complementary exhibits are a large variety of pipe joints from which a type can be chosen for any steel-pipe installation, and a collection of modern protective linings and coverings supplied for the various conditions of service.

Parts treated by Follsain Metal Ltd, by their Penetral H.T. process for resistance to oxidation and sulphurous gases at temperatures up to 1050°C.

The pipe joints include several types of spigot and socket; welded and loose flange joints, as well as Victaulic joints and Johnson couplings. The Victaulic exhibits include a sample of the recently-developed ring-type joint for the 15-in. high-pressure pipes being supplied at present for the Bulawayo water supply scheme. In the standard joint the sections of the divided housing containing the leak-proof ring are held together by bolts, which carry the circumferential load imposed on the housing by the internal pressure. In this new type the housing is held together by a pair of continuous, not divided, steel rings which engage with taper surfaces on the housing, and force its parts into close contact. These steel rings are in turn drawn together by bolts which are subject to practically no stress other than that due to tightening them up, since the taper of the engaging surfaces is too slight for the internal pressure to produce any axial reaction on the securing rings. Contact between the sections of the divided housing is better initially, and is better maintained under high pressure.

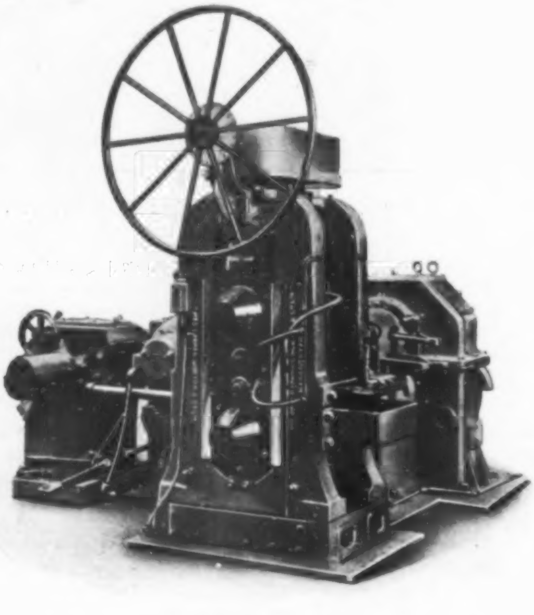
The employment of tubes for fabricated products is increasing, and there are two tubular-steel road trestles shown on the stand. These trestles can be closed up when not in use, and therefore while they serve their purpose better than wooden trestles they also take up less room when being transported from place to place. Decorative panels for fencing purposes, coils forming lamp standards also indicate the variety of articles suitable for fabrication from tubes.

The Stanton Ironworks Company, Ltd. are featuring the various types of self-adjusting pipe joints which they manufacture on spun-iron pipes, and their stand is designed to show that these joints are available for use in place of lead-caulked or turned-and-bored joints. An effective demonstration of the flexibility of the Stanton-Wilson self-adjusting joint is provided by a pipe which is rotated at its spigot end while remaining anchored at the socket end by one of these joints.

Gas engineers will be interested in the Stanton screwed-gland joint. On the stand this joint is used on a length

of pipe which, in spite of being constantly vibrated, holds an internal air pressure of approximately 50 lb. per sq. in. A new self-adjusting joint which is now available under the name of "The Stanton Roll-Ring Joint," is also demonstrated. Cut-away sections illustrate clearly the principle of each joint, and by means of short lengths of pipe the actual method of jointing can be demonstrated in each case.

The stand of Tube Products, Ltd. is made from electrically-welded steel tubes, chromium plated, and on the stand the firm is displaying stainless- and mild-steel tubes in sizes varying from $\frac{3}{16}$ in. o.d. to $3\frac{3}{8}$ in. o.d. in gauges from 10 to 22. The material can be supplied manipulated, and is used by a large number of trades. Electrically-welded steel tube is now being used extensively for A.R.P. work, and special types are shown for motor, cycle, electrical and engineering trades.



A four-high cold rolling mill for 10" strip by Sir James Farmer Norton & Co. Ltd.

The exhibit of the Chesterfield Tube Company, Ltd. will consist of cold-drawn weldless-steel steam pipes for high-pressure steam installations, weldless-steel headers for boilers and superheaters, and tubes manufactured from the latest corrosion- and heat-resisting alloy steels. Weldless steel cylinders, for the storage of permanent and liquefiable gases will also be displayed, and these exhibits will comprise cylinders ranging from large storage bottles manufactured for capacities of over 6,000 cu. ft. to the small medical and aircraft cylinders, weighing only a few pounds. Another interesting exhibit will be a weldless steel hollow measuring 29 in. internal diameter by 3 in. thick by 17 ft. long, manufactured by the new plant recently installed at this company's works.

Tools and Tool Materials

The engineers' tool department of Thos. Firth and John Brown, Ltd. will be fully represented by a range of files, machine tools, "Speedicut" high-speed steel drills, reamers, cutters, butt-welded lathe tools, carbide-tipped tools, "Millenicut" files, hacksaw blades, Insto-segmental saws, the Firth Hardometer hardness-testing machine, long saws, cross-cut saws, wide and narrow band saws, etc.

Edgar Allen and Co., Ltd. will show a comprehensive range of their branded tools, particular attention being directed to Allenite tungsten-carbide-tipped tools and tips for cutting cast-iron and non-ferrous materials generally, chilled-iron rolls, and, in certain circumstances, for cutting steel. Butt-welded high-speed steel-cutting tools will also be much in evidence. An interesting range of tools is also shown by Frys (London), Ltd. It includes several additions to the "Enox" series which are exhibited for the first time; noteworthy is the "Enox" tube cutter No. 2, which has a capacity up to $1\frac{1}{4}$-in. copper pipe. Attention is also directed to the brands of hacksaw blades

An entirely new range of standard tools tipped with "Wimet" tool metal is displayed by A. C. Wickman, Ltd. These new standards are the result of co-operation with machine-tool makers in an effort to give designs which will cover all general machining operations, and Wimet tips have been designed to avoid all unnecessary waste. The grades include "Grade N" for cast-iron, non-ferrous materials and general purposes; "Grade H" for chilled-iron rolls and highly abrasive materials; "Grade X" for steel of all grades; "Grade XX," for finishing cuts at high speeds on steel; "Grade X8," for medium cuts on steel; "Grade S.58," for heavy cuts on steel; and "Grade G," for wood-working.

Wimet XX opens up a new field of application on account of its resistance to pitting and cratering from chip flow. Earlier grades of Wimet, consisting of cemented tungsten carbide alone, were very susceptible to chip action on account of the high affinity for steel which is a characteristic of tungsten carbide. The addition of titanium carbide in certain proportions gives a great resistance to cratering, increasing the cutting efficiency and longevity of the tool. It is being used in increasing quantities and a large number of steel applications are being performed with great success. Wimet X8 and S.58 have the same advantage as regards resistance to pitting, but have the additional advantage of resistance to shock, particularly S.58, which grade can be used with the same feeds and depth of cut as high-speed steel, but at lower speeds than the ordinary grades of tungsten carbide.

Heat-resisting Products

Apart from the special steels designed for heat-resisting purposes, there are a number of products which will withstand relatively high temperatures, such as the Calorised mild steel and Calvert nickel-chrome heat-resisting steels of the Calorising Corporation of Great Britain, Ltd. These are used for heat-treatment containers, cyanide, salt and lead hardening and annealing purposes. They are also proving valuable for nitrate of soda baths for the heat-treatment of aluminium alloy parts, supports for oil-cracking stills, etc.

The associate company of Follsain Metals Ltd., the Wycliffe Foundry Company, Ltd., exhibit a number of specialities in this field which include sootblowers, carburising and cyanide pots, pyrometer sheaths, and various furnace parts treated by their Penetral HT process which gives to iron and steel complete resistance to oxidation and sulphurous gases at temperatures up to 1,050° C., and also resistance to the attack of seawater; various furnace parts and castings made in thin EVHI, heat-resisting alloy which combines high creep resistance with immunity to oxidation and the attack of sulphurous gases at temperatures up to 1,175° C.; pallet bars in heat-resisting iron for sinter plants, etc.; and castings such as locomotive brake blocks, coal mill and stone-crusher parts, shute plates, etc., in their CY abrasion-resisting metal which gives a resistance to abrasive wear at least equal to that of manganese steel. Castings also which possess a very high resistance to wear where heavy abrasion is accompanied by severe shock; this metal is particularly suitable for the wearing parts of certain types of high-speed pulverising machines.

Steelworks Plant and Equipment

As a rule, steelworks plant is not suitable for exhibits, and the few firms represented at the Fair who specialise in this section display large photographs of plant installed at various works of these are the exhibits of Gibbon Brothers, Ltd., whose photographic illustrations include

several of the well-known "Gibbons-Kogag" coke-oven plants, views of complete ovens and work under construction. Full technical information regarding these ovens is available.

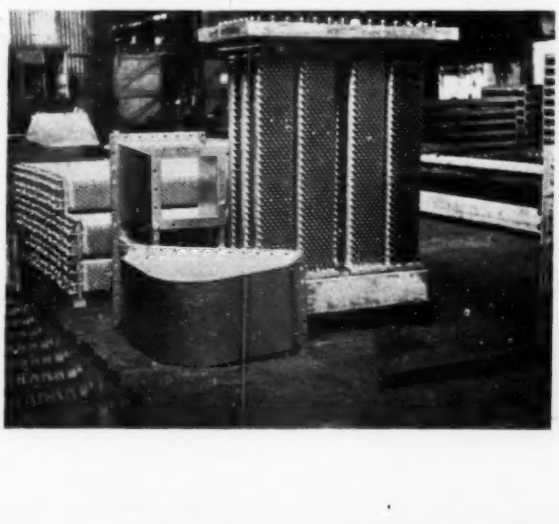
Electric power plant and instruments for steelworks is displayed by the principal electrical companies. The General Electric Company products, for instance, range from large power plant to small measuring instruments. Heavy engineering will be represented by a 500-kW 600-volt (1,000-kW. 1,500-volt) steelclad mercury arc rectifier of the pumpless air-cooled type developed by the G.E.C., and an 11-kV. metalclad switchgear unit of the S.V.D. type, while a typical ironclad switchboard (used also for controlling the supply to some of the exhibits), and a range of certified apparatus for lighting, heating and communication service in dangerous situations will also be on view.

Air heaters and recuperators are shown by Newton Chambers and Co., Ltd. The former is a type suitable for working in conjunction with any type of boiler. The particular unit shown illustrates how the air heater may be mounted in the same setting as the economiser. The recuperator shown is arranged for use with a furnace having a horizontal chimney flue; these recuperators, however, are built up from single elements, and may be made to any desired shape or size to suit local conditions.

In addition to the vertical type shown, the elements can be erected horizontally either above the furnace or at the sides. The needles recuperator is used for preheating both gas and air required for combustion on any type of furnace. The elements used are of the well-known needle type which are equipped with streamlined needles on both the outside and inside of the oval tubes. For working with waste gas temperatures up to 1,100° C., and air temperatures up to 750° C. the elements are cast from a 35% chrome mixture; for lower temperatures, say 850° C. on the waste-gas side, and 450° C. on the air side, they are cast from special heat-resisting iron.

Heat insulation in industry has never been more important than it is to-day. No thermal insulator is available which corresponds to the ebonite used in electrical work, and consequently the elimination of losses due to heat leakage becomes a major problem in many plants, and many people will be interested in the range of insulating materials displayed by Newalls Insulation Company. It includes exhibits of Newalls' 85% magnesia, and "Newtempheit" high-temperature products, together with their "Empire" type 85% magnesia sectional pipe covering designed especially for the insulation of hot-water piping. This company has now established a new product dealing with the fire protection of girders, stanchions and electric cables known as moulded asbestos, produced in various forms having extensive potentialities in air-raid precaution schemes. Four grades of insulation bricks are also manufactured covering a range of temperatures up to 2,450° F.

Air heater units by Newton Chambers & Co. Ltd.



Malleable Iron Castings

The applications for reliable malleable castings is increasing, and the various displays of responsible firms will be carefully scrutinised with a view to further developments in this direction. Ley's, of Derby, specialise in the production of blackheart malleable castings, and a tensile strength of 24 tons per sq. in. is consistently maintained, in contrast with that of the British Standard Specification of 20 tons per sq. in. Similarly, its elongation is 18% instead of 7½%, and its cold-bend test is 180° C. instead of 90° C.

Machinability is a vital feature, and malleable castings with hard spots cannot be tolerated in modern production programmes, and Ley's claim that their castings possess exceptional free-cutting properties, due to graphitic carbon and absence of hard spots, which permit high machining speeds with reduced wear and tear on tools. Typical castings are shown.

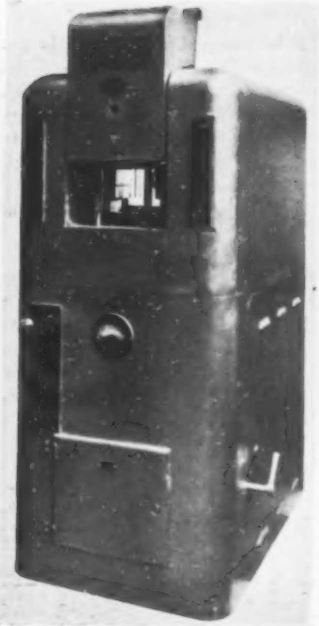
A nine-block continuous wire drawing machine by Sir James Farmer Norton & Co. Ltd.

Refractories

A comprehensive range of refractories which cover the bulk of industrial needs is shown by Gibbons (Dudley), Ltd., 95% silica goods are exhibited in the form of bricks, segmental gas retorts and coke-oven shapes, the very accurate finish being noteworthy. The "HT-1" brand refractory insulating brick is displayed both in the form of standard bricks and special shapes, and should prove of considerable interest to all furnace users and builders. The exhibit is completed by a range of fire clay and aluminous materials, and super refractories made from such materials as silicon carbide, fused alumina and "Sillimanite."

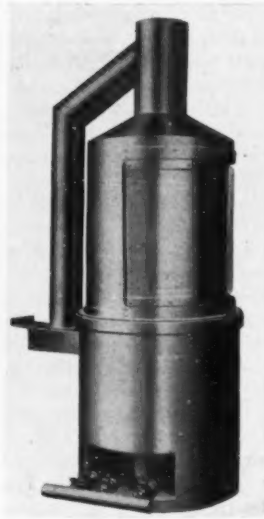
The exhibit arranged by Messrs. John G. Stein and Co., Ltd., is, in general, composed of samples drawn from the standard range of machine-pressed sizes, with representative groups of special shapes in their various brands. Of outstanding interest is the extension of this company's range by a valuable group of chrome and magnesite refractories. These have a very wide range of application in the metallurgical industries and are, therefore, well worthy of attention.

Another comparatively recent addition which is finding increasing use in service is Stein Acid, an acid-resisting brick with low absorption, and high resistance to the corrosive effect of acid liquors. Not less important, however, are the widely-known brands manufactured. Nettle 42/44% Al_2O_3, Thistle 35/37% Al_2O_3, Stein Glasgow 33/35% Al_2O_3 are well in evidence, as also are the Bluebell and Myrtle brands, both 95% SiO_2; while for the more



Wild-Barfield high temperature electric furnace with "Counter-scale Curtain" atmosphere control

"Birlec" 35 kw. furnace for the continuous scale-free hardening of small parts



A Selas low temperature salt bath pot furnace

vulnerable positions in furnaces there are recommended a number of high alumina products, notably Stein 73, Stein 63 and Stein Sillimanite, whose properties at high temperatures of withstanding load and corrosive influences are of particular value.

The range of refractory cements and plastic ramming materials available in this display is adequate for all industrial purposes, and the value of suitable bonding material is well-known. Interest in the exhibits is considerably heightened, in so far as model furnaces are being shown, which are designed to show the recommended type of refractory for the various furnace positions.

Non-Ferrous Metals

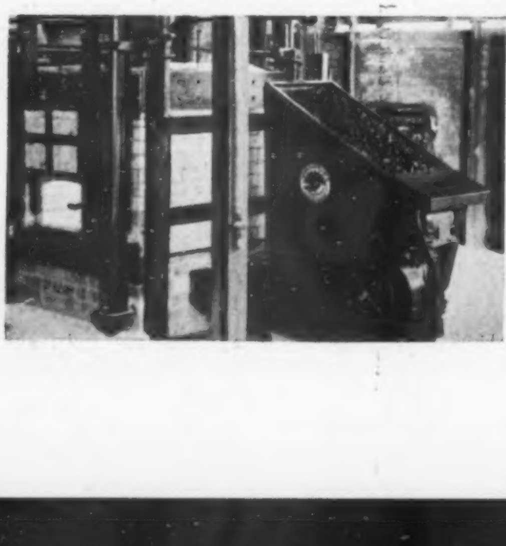
The needs of the engineering industries continue to make increasing demands on metallurgical progress, and rigid production control together with uniformity of quality are now recognised as essential in the development of the non-ferrous industry. Manufacturing technique has also advanced as a result of new equipment installed in many works, and the range of high-grade materials is very comprehensive, particularly the semi-finished materials which are available in so many forms and sizes and in a very wide range of compositions.

A special feature is made of the standard forms in which aluminium is produced in the various works of the British Aluminium Company. By far the largest producer of virgin aluminium in the British Isles, this company will exhibit rolling blocks weighing up to 400 lb.; extrusion billets; strip, in coils weighing up to 500 lb.; sheet in various sizes and tempers up to 10 ft. by 7 ft. 6 in.; circles, tubes and extruded sections; virgin aluminium ingots from 99·0% to 99·8% purity; super-purity aluminium of 99·99% purity; casting alloy ingots to various standard specifications; and alloy hardeners.

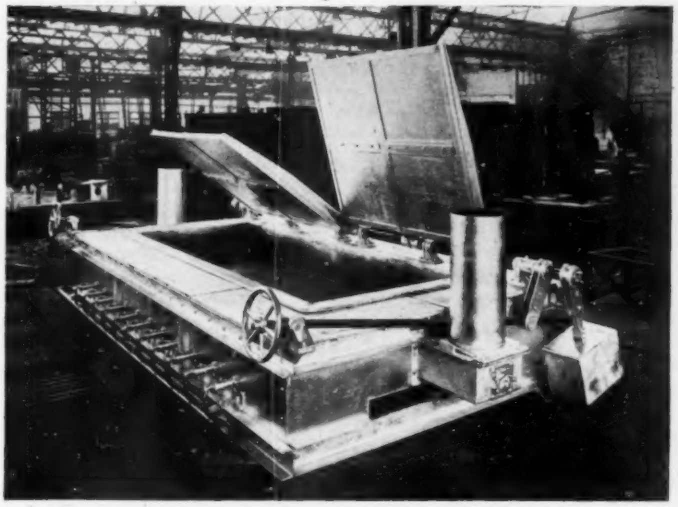
The exhibits will demonstrate the manifold uses of aluminium and its alloys, among which are several developments of particular interest. Some indication of the applications of this metal are given elsewhere in this issue, but readers will appreciate the progress made when it is realised that over 20,000 miles of steel-cored aluminium conductors are now in use on the "Grid" system of the Central Electricity Board. Extruded section in pure aluminium and aluminium alloys can now be produced in an enormous variety of shapes and sizes at a relatively low expenditure on tools. Machined exhibits in RR 56 and RR 59 alloys, aerial castings, and BA/35 free-cutting alloy components show the accuracy with which aluminium alloys can be machined on automatic and capstan lathes. The finish obtained on this metal is also remarkable, including silver and coloured anodic films and sand-blasting.

Development in the application of extruded sections is admirably shown on the stand of Reynolds Tube Company, Ltd. Here the framework and windows are constructed from light-alloy extruded sections, and the pillars at the front entrance illustrate an ingenious use of hollow

An automatic stoker by Mirrlees, Bickerton & Day



A complete scale-free annealing plant by G.W.B. Electric Furnaces Ltd. for steel bars, with protective atmosphere supplied by this firm's latest type of town's gas plant



A typical salt bath furnace by Incandescent Heat Co. Ltd.

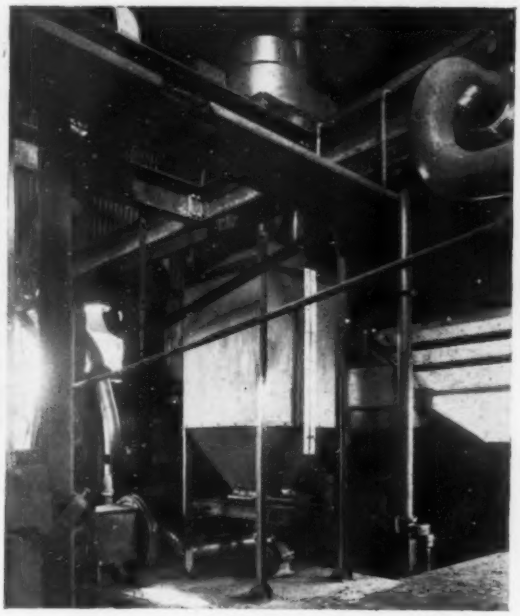
extrusions, indicating also the manner in which the coloured anodic treatment can be applied to work of this nature. The panelling is all carried out in light-alloy sheeting.

The exhibits consist of light-alloy tubes, of all types and sizes, the light alloys being in the well-known Hiduminium "RR" range. The very wide range of extruded sections exhibited indicates the growing use in industries generally of the extrusion process where light alloys are concerned. In addition to light-alloy steel, high-pressure tubing in the well-known "Barronia" metal will also be exhibited. This latter tubing has been specially developed for high-pressure work in aircraft, for use on gun-actuating mechanisms, gun turrets, flaps, etc., and tubes of small gauge and diameter have successfully withstod test pressures up to 15,800 lb. per sq. in. before bursting.

"Kynal" aluminium alloy, suitable for the aircraft and other industries, will be shown by I.C.I. (Metals), Ltd. in sheet, strip, rod and tube. Aluminium and its alloys are becoming increasingly important, not only for aircraft manufacture, but for transport generally. By making greater use of light alloys, railway, road transport and marine engineers find that they can effect an overall reduction in weight with a concomitant increase in pay load. This company will also show brass and other alloys of copper in the form of plates, sheet, strip, wire, rod and sections; strip and sheet in copper and its alloys in various sizes and gauges, and a selection of rods and extruded sections which indicate the wide range of the company's products.

A comprehensive display of tubes of various sizes and qualities will be staged on the stand. The condenser tubes for s.s. *Queen Mary*, in cupro-nickel, were supplied by I.C.I. (Metals), Ltd., and similar tubes are now being supplied for her successor, s.s. *Queen Elizabeth* by the same firm. "Everdur," copper with the strength of steel, has made great headway since the last Fair, particularly in the manufacture of boilers, cylinders, storage tanks and heaters, and for all purposes connected with water conveyance. Special attention will be drawn to the ease with which "Everdur" can be welded by oxy-acetylene, carbon arc or resistance methods. Other exhibits of interest to those engaged in constructional work will include expansion jointing which is finding a considerable outlet in concrete construction: "Kudampro," copper strip for damp-proof courses, and "Terrabond" serrated strip for terrazzo flooring.

A gas tube furnace by Incandescent Heat Co. Ltd.

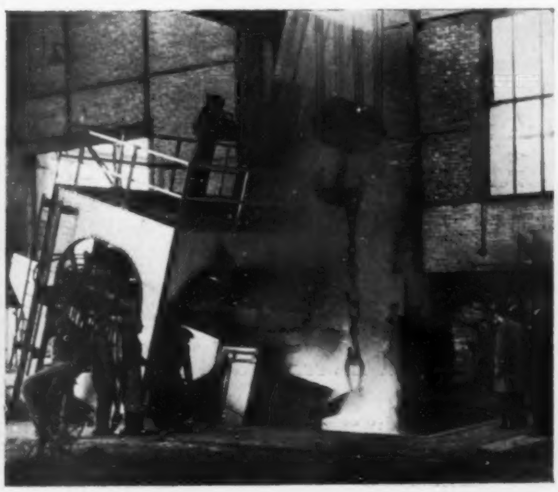


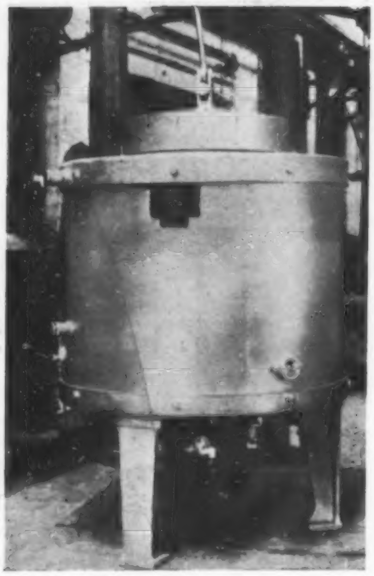
A typical Atritor installation for firing forge furnaces on the ring main system

The usual comprehensive range of non-ferrous alloys will be exhibited by Messrs. T. J. Priestman, Ltd., and will include examples of aluminium sand and die-casting alloys, and a full series of pre-alloys. Brasses and bronzes are also displayed together with newer developments in gravity- and pressure-cast brasses, high tensile, manganese and aluminium bronzes.

A comprehensive display of the manufactures of Serck Tubes, Ltd. will embrace many new sections which have

An electric melting furnace by Metalectric Ltd.





A recirculation pot furnace by Bradshaw Furnaces & Tools Limited

not previously been shown. In addition to their full range of non-ferrous tubes in brass, copper, aluminium, gilding metal, bronze and Admiralty metal, this company is making a further display of alloys which have been found to reduce to a minimum the corrosion met with in circulating and cooling plants. With regard to service copper, users are now more fully alive to the advantages of a smooth bore tube, and special attention has been paid to this, also to the purity—the copper being guaranteed of a purity of 99·9%, which is highly suitable for bronze or copper welding; in addition these tubes are made in a temper suitable for manipulation without further heat-treatment, paying particular attention to temper required for special joint fittings. This company specialise in very light gauge tubing to a wall thickness of five thousandths in brass, copper, and cupro nickel.

Considerable interest will be taken in the display by the Yorkshire Copper Works, Ltd., in which they show non-ferrous tubes in all qualities for water services, heating, waste, gas and pipe lines of all description. The company produce tubes in all qualities—viz., copper, brass, aluminium, cupro-nickel, phosphor-bronze, "Yorcalbro" (aluminium brass), black tin, etc., and specialise in the production of the "Yorkshire" fitting for the connection of copper tubing for water and heating installations, gas services, refrigeration and general engineering purposes.

Modern industry demands efficient and clean methods and materials which also facilitate speed in production. As the result of intensive investigation on the part of Johnson Matthey, metallurgists, industry has been offered a range of silver solders which are now regarded as essential in many types of engineering production. The process of silver soldering is, however, one that finds application not only by shipbuilders, engineers, chemical plant manufacturers, electrical engineers and coppersmiths, etc., but also by many model engineers and other small users. Accordingly, in addition to demonstrating many of the possible uses of silver solders, this firm is introducing a complete outfit suitable for small brazing and silver soldering jobs at a price which will appeal to the small and the occasional user. A new silver-solder alloy will also be demonstrated, possessing a lower melting point than has previously been obtained in a solder of this type.

For many years Johnson Matthey have specialised in the production of silver-lined copper vessels for certain types of processes in the chemical, food and brewing industries. This year research into the problem of bonding silver on to steel has now reached a promising stage, and examples of the results produced will be on view. The principle is somewhat similar to that of the old-time Sheffield plate, or more recently, rolled gold—in the manufacture of which this firm also specialises.

Precious Metals

The possible uses of the precious metals in industry would appear, at first sight, to be extremely limited. Actually, these metals intrude themselves into our everyday existence to a surprising extent. For instance, every time we switch on our radio or use the telephone or travel in a motor-bus or in an aeroplane, we are calling upon innumerable and perhaps minute electrical contacts made from one or other of the precious metals to perform their allotted task. The analysis and testing of our foodstuffs involve the use of platinum vessels in the laboratory, while many of our modern synthetic materials call for catalytic action by platinum in the early stages of preparation. Most of our domestic china is decorated with gold or platinum, which has been fired on over the original glaze. The whole art of photography is based upon the sensitivity of silver bromide to light rays. Silver nitrate is the product used in the silvering of mirrors and the preparation of printers' blocks. The bactericidal action of silver is a phenomenon which is the basis of one of the modern processes for the purification of water for drinking purposes and swimming pools. Apart from the substantial quantities of gold used in dentistry, rolled gold is a very important material in the optical industry. Silver solders are used extensively in the construction of water heaters and sanitary fittings which are common in all our homes.

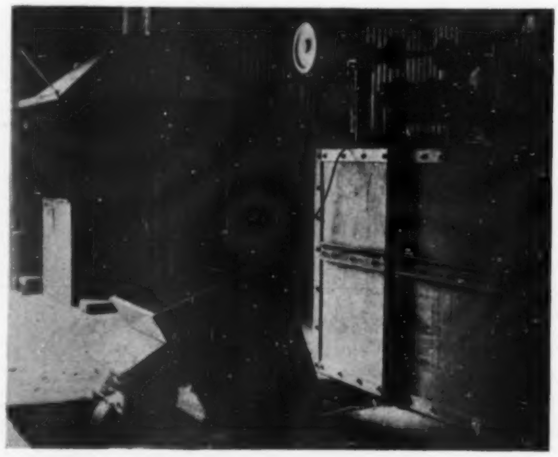
These are more or less common uses of the precious metals. There are literally hundreds of others less commonplace. Thus, many phases of our daily existence are simplified by the judicious application of these metals to which we seldom give a thought other than in connection with their uses as coin or bullion, or in the form of jewellery and articles of silverware. At the Fair, both in London and at Castle Bromwich, Johnson Matthey will give a comprehensive review of these applications.

Heat-Treatment Equipment

Recent years have seen great progress in the production and use of plant and equipment for the important operations involving heat-treatment; they have shown a growing demand for controlled atmosphere in heat-treatment furnaces, and many of the furnaces exhibited at the Fair will emphasise this trend. Among these exhibits is a new continuous belt-conveyer for automatic brazing or bright annealing. Birlec furnaces of this type are already well known, but the new model is of smaller size than has been previously available, and should be useful in making the advantages of brazing and/or bright annealing available to firms whose production does not justify the installation of a large plant.

Birmingham Electric Furnaces Ltd. also show a new type of clean-hardening furnace for continuous production of small parts, shown in actual operation, and is a prominent feature of the display. This unit is exceptionally compact, economical and simple in operation giving a very clean finish on the work with complete absence of decarburisation

A Prior Mastoker firing a heat-treatment furnace



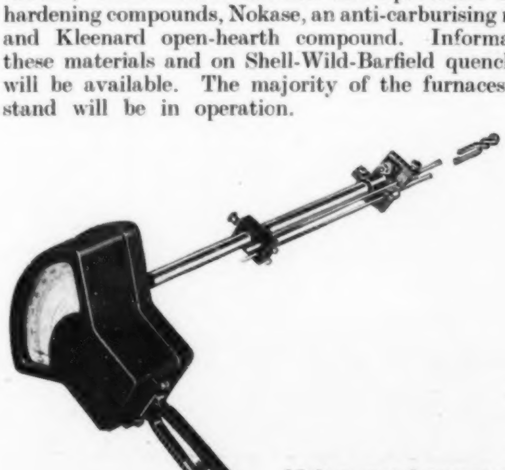
and either oil or water quenching at will. Also shown for the first time is an example of the Birlec 'Lectrodryer for dehumidification in air-conditioning systems. This is an entirely automatic unit in which activated alumina is used as an adsorbent, and it is designed for long periods of continuous use without any attention or maintenance.

Electric furnaces of many different types will be exhibited by Wild-Barfield Electric Furnaces, Ltd., and G.W.B. Electric Furnaces, Ltd., ranging from laboratory muffles to furnaces for industrial use. The small furnaces will be shown in several different types covering a wide range of laboratory requirements. In addition, some of these furnaces are suitable for works use for hardening small tools, etc. A box-type furnace suitable for carburising, reheating, normalising, etc., will be shown. This is a furnace with a hearth 4 ft. by 2 ft. wide, fitted with patented "Tubular Hairpin" heating elements designed for continuous use up to 1,100° C., and for periods up to 1,150° C.

For high-speed steel hardening three equipments will be exhibited. The first is a small twin-chambered unit for toolroom use; the second is a larger unit comprising two separate furnaces, both of greatly improved construction and appearance. The preheating furnace is of the "Hairpin-Minor" type, and is also suitable for the majority of heat-treatments from 700° C. to 1,000° C. The other type of high-speed steel-hardening furnace is an electrode salt bath which incorporates many novel features designed to give safe and efficient operation.

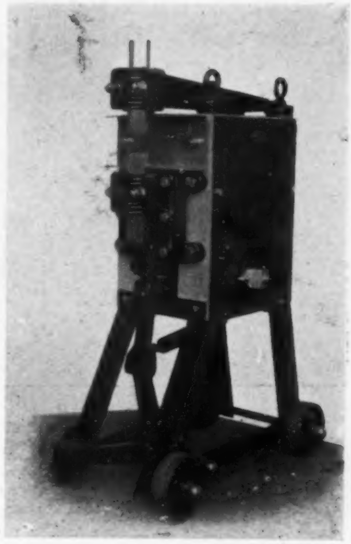
For low-temperature treatments below 700° C. two sizes of vertical forced-air circulation furnaces will be shown. One furnace fitted with the Charge Progress Recorder is intended for production, the other smaller model of simplified design for toolroom and experimental purposes. Another furnace of considerable interest to the light-alloy industry is a small batch furnace with forced-air circulation, now widely used for heatings mall billets prior to forging.

The furnaces manufactured by Messrs. G.W.B. Electric Furnaces, Ltd. are too large to exhibit, but numerous large photographs of installations will be on view. The hardening shop requisites distributed by them will be shown; these include Eternite and Speedicase box case-hardening compounds, Nokase, an anti-carburising material, and Kleenard open-hearth compound. Information on these materials and on Shell-Wild-Barfield quenching oils will be available. The majority of the furnaces on this stand will be in operation.



Molten metal pyrometer by Ether Ltd.

Of great interest will be the display of the four companies comprising the Incandescent Group, which are the Incandescent Heat Company, Ltd., the Selas Gas and Engineering Company, Ltd., Metalectric Furnaces, Ltd., and Controlled Heat and Air, Ltd. This group consolidates the combined resources of a group of industrial furnace engineers—mechanical, gas and electrical engineers and metallurgists—of highly specialised experience in the design and application of furnaces and combustion equipment to every phase of the metallurgical and engineering industries.

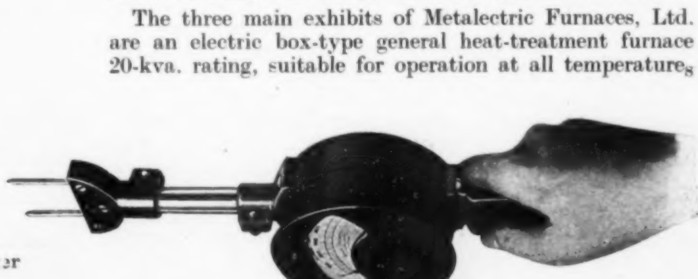


One head electric rivet heating machine by Holden & Hunt Ltd.

Apart from a comprehensive range of photographs illustrating the larger type of units manufactured, the main exhibits include a cylindrical Incandescent-Lee Wilson bell-type furnace, by Incandescent Heat Company, Ltd., for bright annealing ferrous and non-ferrous wire and strip in coil form. This furnace is designed for firing by gas on the Lee Wilson vertical radiant-tube principle. It is operated in conjunction with three or four bases upon which are placed the charges surrounded by inner covers, of exceptionally low thermal capacity, and which are filled with purging gas, thus protecting the work under treatment from oxidation and discoloration; a small salt bath which is representative of the much larger installations that have been completed during 1938; a recuperative gas-fired furnace of standard type and a high-speed steel-hardening furnace.

The Selas Gas and Engineering Company, Ltd. designs and manufactures industrial gas equipment for all purposes in all trades, and is showing a wide range of exhibits which include gas- and air-mixing and proportioning apparatus for use in conjunction with any gas-fired plant resulting in complete combustion and consequential economy in fuel costs; a new low-temperature salt-pot furnace unit operating at temperatures up to 600° C., suitable for the treatment of duralumin and light-alloy rivets and other small pressings and components; and other equipment embracing natural-draught gas-burner injectors, immersion heating equipment, gas and pressure air burners, gas-fired muffle furnaces, muffle soldering stoves, internally-heated soldering iron, soldering iron stove, gas blowpipes, laboratory crucible furnace, laboratory Bunsen burners, fuel oil burners, and controlled radiant flame burners.

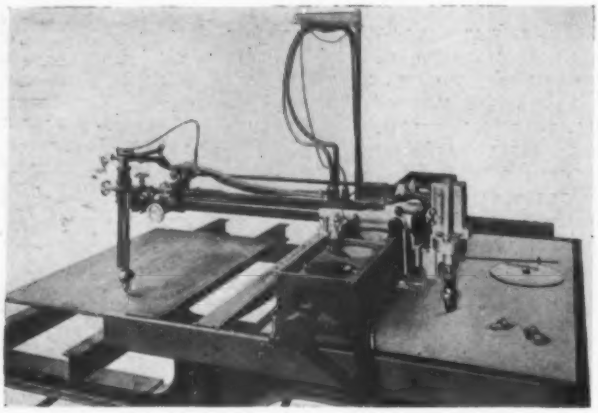
The three main exhibits of Metalectric Furnaces, Ltd. are an electric box-type general heat-treatment furnace 20-kva. rating, suitable for operation at all temperatures



Surface contact pyrometer by Ether Ltd.

up to 1,000° C.; a vertical air-circulation furnace, suitable for operation at all temperatures up to 700° C., and equipped with automatic temperature control; and a model electric steel-melting furnace, a replica of a 12- to 15-ton capacity Metalectric-Tagliaferri three-phase direct arc-type melting furnace.

A full-sized conveyer bright annealing furnace by Incandescent Heat Company, Ltd., at work on the B.G.F.



Universal Simplex flame cutting machine by Hancock & Co. (Engineers) Ltd.

industrial gas exhibit will be one of the outstanding features of this year's Fair. This stand has a reputation for its interesting working exhibits which have included glass manufacture, flame cutting, die-casting and a special process for hardening high-speed steel tools. In the past, however, so many other pieces of gas equipment have been shown as well that there has been little room for really striking display. But this year the number of exhibits has been cut down to four, and some really fine display work has been put into the stand.

The "Gas Tube" principle of gas-firing which is used in the bright annealing exhibit, is one which is just being developed and which promises to be of the utmost importance. It takes the place of the muffle system of firing, and is used only where the load must be kept separate from the products of combustion. It does not, therefore, affect the use of open-fired gas furnaces which are standard practice for most ordinary heat-treatment purposes, as well as for forging and billet-heating, and even for clean annealing.

The conveyer gear of the furnace shown is also notable in that the driven rollers which make up the hearth are made of refractory material throughout, and therefore need no internal cooling. The results obtained are quite remarkable in quality as well as cost, and visitors are invited to bring their own specimens for test.

The main feature of Messrs. Gibbons Brothers' stand is a series of illuminated photographs depicting various plants erected by the firm during the past year. This is a departure from their usual practice of exhibiting a working furnace; they feel, however, in view of the wide and varied nature of their activities that this year's arrangement will appeal to a greater section of their customers than a single furnace exhibit could do.

Another process which is of growing importance, and which has set furnace makers some difficult problems is the medium-temperature heat-treatment of metals, particularly light alloys for aircraft construction up to, say, 600° C. The permissible temperature variation is very small, and recirculation of the furnace atmosphere is essential. A pot furnace of this type by Brayshaw Furnaces and Tools, Ltd., is shown on the stand. The work is loaded into a wire basket 16 in. deep by 16 in. diameter, and lowered into a metal receiver heated on the outside by natural-draught burners in an insulating refractory outer casing. The air inside the receiver is recirculated by an impeller projecting through the bottom plate of the furnace. The gas rate is controlled by a bimetallic thermostat and a two-point recorder by Elliott Brothers, Ltd., with thermo-couples at the top and bottom of the basket registers the exact state of the load.

The more everyday uses of gas are represented by an open-fired furnace by Gibbons Brothers, Ltd., for general heat-treatment with an automatic control panel by the Cambridge Instrument Company, Ltd., and by a new recuperative crucible furnace by Constructional Engineering Company, for melting non-ferrous metals. A new gas-furnace control panel is also shown for the first time.

Several gas-heated and electrical furnaces will be shown in operation on I.C.I. stand in order to demonstrate the following salt-bath heat-treatment processes: Rapideep for deep carburising; cyanide for shallow carburising and general heat-treatment; tempering salts for low-temperature operations such as colouring of steel; and hardening of high-speed steel in carboneutral consisting of pre-heating, hardening and quenching in molten salt.

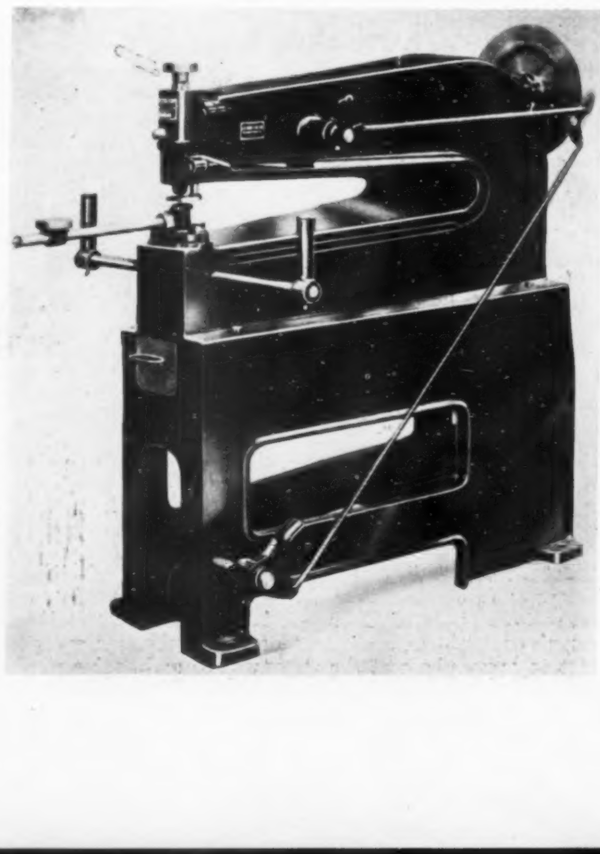
An Atritor unit coal pulveriser firing a furnace and lead pot is shown by Alfred Herbert, Ltd. It has a capacity of 500 lb. of coal per hour, and delivers the pulverised coal into a small cyclone-service bunker holding about one ton of pulverised coal; under normal conditions this would be equal to four hours requirements. At the base of this bunker there is a motor-driven feeder. This delivers the pulverised coal at the desired rate into a fan which, in turn, conveys it to the main, running round the stand.

The forge furnace is of a size commonly used for small drop stampings and consumes from 40lb. to 50 lb. of coal per hour. The lead melting pot which will require only about 6 lb. to 8 lb. of coal per hour will also be shown in operation. This lead pot is probably the smallest type of furnace to be fired by pulverised coal. The furnaces are easy to light, and a mellow soaking heat with non-oxidising flame is obtained. Cleaning and banking of fires are eliminated and labour costs are low.

Pyrometer Equipment

The tremendous activity due to the aircraft and armament programmes during the past year has had a great influence on the trend of pyrometer design. The tolerances in heat-treatment operations are, in many cases, so small that proper instruments are now practically essential. The fine limits of temperature required for the treatment of light alloys, for instance, has led to the development of equipment to ensure the utmost accuracy. Of interest in this connection is the Ether "Indicorder," a continuous-chart recording and controlling pyrometer, which is capable of recording and controlling Duralumin treatment baths at a temperature of 490° C. to the limits of ± 2° C.

A nibbling machine by J. B. Stone & Co. Ltd.



Ether, Ltd. are also showing a portable surface contact pyrometer which has been developed to measure light metal billet temperatures prior to and during the forging operations; a portable indicator which embodies refinements calculated to ensure a high degree of accuracy; and a molten-metal pyrometer. Perhaps the greatest strides during the year have been made in the more extensive use of the highly-complex light alloys, and since the first and most vital operation of the fabrication of these alloys is the melting of them, instruments, such as the molten-metal pyrometer, for the measuring and controlling of melting temperatures have been the subject of much attention.

Several furnaces exhibited are equipped with pyrometers by the Cambridge Instrument Company, Ltd., who constructed the first industrial pyrometers nearly 40 years ago, some of which are still in regular use. Since the earlier days of industrial pyrometry great advances have been made in the accurate measurement of temperature which are reflected in the development of these temperature-measuring instruments.

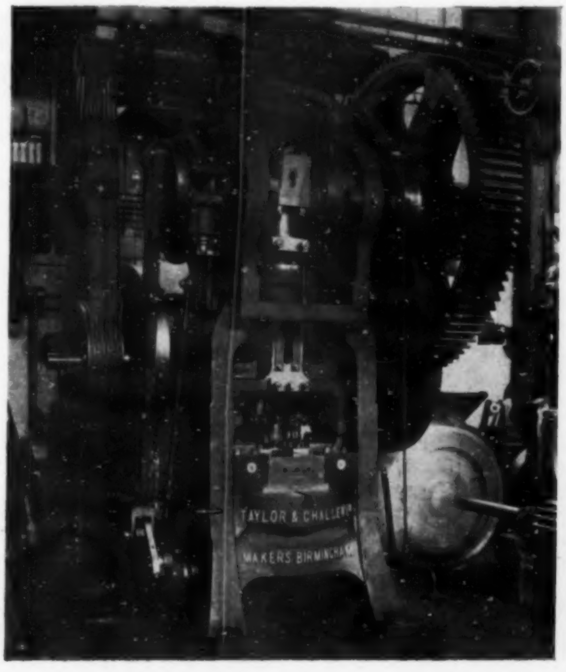
Mechanical Stokers

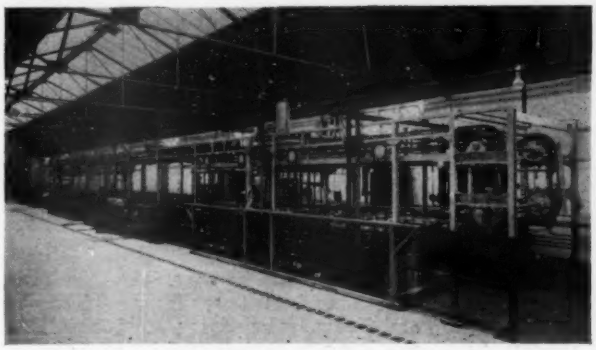
Not the least interesting of the exhibits of Mirrlees, Bickerton and Day, Ltd., is a "Mirrlees-Combustioneer" firing a Ruston No. 7 Thermax vertical boiler in which the steam pressure is automatically maintained by means of a thermostat which stops and starts the stoker according to the needs of the boiler. Another exhibit is of a similar stoker, but this time applied to an "Ideal" sectional boiler, fitted with thermostats arranged to maintain the water in the boiler and heating system at any desired temperature.

These automatic stokers cover a very wide range of applications, and are made in sizes from those suitable for firing small domestic boilers, to large models delivering up to 1,200 lb. of coal per hour. There are models for central-heating boilers, steam-raising boilers; they are also providing controlled heat—with economy—to many industrial furnaces, forging annealing, and heat-treatment furnaces generally, vitreous-enamel furnaces, and many more applications.

Prior Burners, Ltd. are also exhibiting automatic stokers designed for use with any existing vertical or

Crank press machine exhibited by Taylor & Challen Ltd.





An automatic plating plant by W. Canning & Co. Ltd., a working model of which is on view

horizontal boiler. It is an under-feed stoker, the fuel hopper being connected to the burner by a worm feed. A fan supplies air combustion, and the worm gear itself is driven through a five-speed gearbox by an electric motor. Fuel is under-fed by the worm-feed to the burner, where it becomes pre-heated; volatile matter is released and is completely burned in its passage through the fire-bed. The control is automatic, and fluctuations are therefore avoided. There is a saving of up to 40% on fuel, since cheaper grades of coal can be used, and up to 85% is saved on labour charges.

Miscellaneous Machines

The increasing use of tube for a great variety of purposes has resulted in the development of a high-speed tube-straightening machine which is also applicable for straightening bar. A machine of this type is exhibited by Joshua Bigwood and Son, Ltd., capable of straightening bar and tubes at a speed of 225 ft. per min. The maximum size of bar taken in the machine shown is $\frac{7}{8}$ in. diameter and 1-in. diameter tube, but these machines are built in a series of standard sizes, the largest of which will straighten bars and tubes up to $18\frac{1}{2}$ in. diameter. This company recently took over the goodwill and stock of the Britannia Lathe Company, whose lathes they are redesigning to meet modern machinery technique, and one of the improved standard models will be on view.

With progress in flame cutting and welding machines several firms who specialise in these types of equipment provide interesting displays, since the majority of machines shown will be demonstrated. Of these mention may be made of the latest Universal Simplex machine shown by Hancock and Company (Engineers), Ltd. Although this machine has the same flame cutting area as the earlier model, it is of greatly-improved construction and may be regarded as an entirely new machine. The tubular construction of the main carriage of the former models has been replaced by a braced plate construction, giving greater rigidity and easier and speedier running. The machine is fitted with a standard universal electric tracer head operating from an indefinitely-variable gear enabling the cutting speed to be instantaneously set by means of a sliding pointer and graduated scale. This firm also shows a direct cutting and profiling machine, a portable automatic straight line and circle machine and a profile shearing machine.

A wide range of low-voltage resistance welding machines will be shown by Holden and Hunt, including spot, continuous-stitch spot, butt, flash-butt types, and rivet heaters. A new development to be shown is a single-head 12-kw. electric rivet-heating machine which, like the two- and three-head types, has a fabricated angle framework and is arranged with wheels for floor use and eye bolts for crane lifting. Every care has been taken to embody all the features in the design of this machine which long experience of rivet-heating machines has shown to be

necessary. A complete range of spot-welding machines will be shown, including the 5-, 10-, 15-, 25-, 40- and 50-kva. capacity machines, all of which are designed to fill the needs of modern high-speed and heavy-duty spot welding. Also on view will be a 15-kva. spot welder with a weld time valveless time gear, in which several new features are embodied ; a 25-kva. electric continuous-stitch spot-welding machine, in which many improvements on previous designs are incorporated ; a range of automatic butt welders covering a welding capacity from $\frac{1}{32}$-in. diameter to $1\frac{1}{2}$-in. square—the smallest size is built almost entirely in aluminium, and only 60 lb. in weight ; and two machines of the universal type of flash-butt welding machines will be shown, of 20- and 60-kw., respectively.

Messrs. Sir James Farmer Norton and Company, Ltd. are showing one of their standard four-high rolling mills. The roll stands of this machine are of cast steel with rolls $5\frac{1}{4}$-in. and $12\frac{3}{4}$-in. diameter, and 12-in. barrel length, giving a maximum width and rolling at 10 in. wide. Backing rolls are supported in cast-steel chocks fastened with self-adjusting roller bearings. For the support, and in order to obtain correct alignment, of the work rolls, the mill is fitted with patented adjustable side bearings. Another interesting feature of this mill is the method of surface cooling the four rolls. This is done by a complete circulating system, and the temperature of the rolls can be controlled as required. On the in-going side of the rolls a strip cleaner is provided, and on the out-going side a self-contained coiler unit is shown.

This firm will also exhibit two types of their continuous wire-drawing machines built on the non-slip principle. These machines will be working on the stand. It is noteworthy that each unit is self-contained and each block independently driven, so that additional units can be added if desired, in the future. The machines can also be divided into sections and utilised for short holing work with any combination or sequence of blocks.

J. B. Stone and Company, Ltd. are showing a new model in their range of nibbling machines ; the earlier types have also been improved and incorporate new features to meet modern requirements. The new machine has a cutting capacity of $\frac{1}{16}$ in. to $\frac{3}{16}$ in. in mild steel, and from $\frac{1}{32}$ in. to $\frac{3}{32}$ in. in stainless steel. The approximate cutting speed is 30 in. per min., and the work produced is claimed to be entirely free from burr or distortion. The gap is 30 in., and a variable stroke is incorporated permitting the use of the same thickness of templet throughout the range of the machine.

Weighing, counting and testing—the three basic activities of W. and T. Avery, Ltd.—will be the subjects of practical demonstration. The latest development in weighing is represented by the transposing unit recorder which provides reset and cumulative totals and also printed records. Considerable interest will be shown in the unit-count machine. In addition to serving a scale and providing visible indication of gross or nett weight, the machine will also determine the variations in weight of repetition articles from a master specimen ; compute material and scrap ; and count the number of units in a bulk quantity.

An example of Avery testing equipment will be shown in the demonstration model of the self-indicating universal testing machine which is designed for carrying out tests in tension, compression, transverse, shearing and hardness. Though particularly suitable for rapid commercial testing, the speed of the machine is readily controllable, and an extremely slow rate of straining can be obtained.

A hot-brass pressing machine with patented features will be exhibited by Messrs. Taylor and Challen, Ltd. This machine is somewhat similar to that shown last year but of larger capacity—viz., 200 tons. For the production of brass pressings having up to four cored holes in them, the machine includes a mechanical vice for holding the dies. The dies, which form the outside of the finished pressing, are in halves, being split in a vertical plane ; one half is fixed in the vice body, and the other half fixed to the sliding member of the vice, which is actuated by a powerful toggle mechanism, which grips with great pressure so as to prevent the escape of a flash. The four cores are formed on punches, one of which, carried on the main slide of the press, applies the pressure necessary to extrude the metal over all the punches. The other three are carried on slides, one on either side of the dies, and one below. These punches enter the die space before the main punch completes its descent, and form fixed cores over which metal is extruded ; they are withdrawn automatically on the upstroke of the press. The resulting product is non-porous, and has a much better finish than can be obtained by casting methods.

The outstanding exhibit of Messrs. W. Canning and Co., Ltd. takes the form of a complete miniature plant, in full working order, for automatic bright nickel and chrome plating. The plant is 23 ft. in length, and visitors will be able to examine and follow closely the working detail. The synchronising of the transfer mechanism which carries the goods from vat to vat is carried out by electrical interlock switchgear operated by the main conveyer chain. This type of gear is a distinct advance over the mechanically-synchronised type, as it allows of the incorporation of a vertical lift and lowering into the process tanks, which saves a considerable amount of space. At the same time a motion is incorporated which gives a dwelling period to the racks, resulting in a considerable economy in drag-out. The plant includes all the usual processes for cleaning and swilling antecedent and subsequent to the plating processes. It is electrically heated, and is complete with all accessories to make a working exhibit.

Another interesting exhibit is a model shop for nickel and chrome plating, including the necessary polishing and finishing equipment ; while other electro-plating equipment includes low-voltage motor generators ; metal-plate rectifier with control panel ; resistance boards of new design with bakelite meters ; electrically-heated centrifugal drying machines ; rotary air pump and compressor used with filter unit ; plating racks covered with the new Korolac insulation ; and a large assortment of electro-plating materials. A number of polishing machines are also shown.

The Coventry Machine Tool Works, Ltd. exhibit several forging machines which include a $\frac{1}{4}$-in. screw nicking machine and a $\frac{1}{4}$-in. thread-rolling machine. These machines, which are entirely automatic, form a plant for the production of cold-formed nicked-head screws—i.e., cheese heads, round heads, and countersunk heads, etc. The first machine is for cold-heading the screw blanks, which is done from a coil of wire, and the second machine rolls the thread on each blank, producing the finished screw. The production from these machines is at the rate of 100 screws per min.

Trade Marks and Their Protection

A CONSIDERABLE alteration in the law concerning trade marks has been embodied in the Trade Marks Act 1938, but the Act contains many provisos and exceptions, to prevent possible abuses, making interpretation somewhat difficult.

A new book on trade marks—their nature, ownership and registration—together with such aspects as appeals, oppositions, amendments, assignments and licenced uses ; includes explanation of the new law and practice to trade mark owners and other concerned. It contains, also, a chapter on remedies for infringements, sundry provisions, and protection in British dependencies and colonies, and in foreign countries.

The new classification of goods under the Act of 1938 will form a very useful reference for those interested. This is an informative book, by R. Haddan, published by Pitmans, at 5s. nett.

Defects in Non-ferrous Ingots

By J. L. Bailey, M.Sc.

The more important types of defects liable to occur in non-ferrous rolling slabs were discussed by Mr. Bailey at a recent meeting of the Midland Metallurgical Society. Attention was directed more particularly to brass, but the principles involved are common to all metals and his main features are given in this article.

Surface Defects

ONE of the most obvious and at the same time most easily avoided surface defects is the trapping in the surface of the ingot of folds of oxide skin. In the first place, it is important that the stream of metal from the crucible is clean. If dross is allowed to pass into the ingot, trouble is inevitable, but this is readily avoided by careful skimming, or by the use of a bottom pouring ladle. The cleanest of streams however, is liable to oxidise during pouring and, if exposed to the air, an oxide skin also forms on the surface of the molten metal in the mould. This skin is likely to break and fold, causing more or less serious surface irregularities and preventing, in some cases, the remelting of splashes of metal thrown up on to the mould wall by turbulent pouring. In the case of alloys like brass, composed of metals with readily reducible oxides, the formation of an oxide skin in the mould can be avoided by pouring in a reducing atmosphere.

Where the alloy contains elements with a high affinity for oxygen, such as aluminium, a volatile oil-base coating is ineffective in preventing oxidation. With such alloys, oxidation cannot readily be prevented and oxide folds in the surface of such ingots are best avoided by methods of non-turbulent pouring, in which advantage is taken of the strength of the alumina skin. Alloys containing aluminium can be successfully poured by ensuring that the oxide skin is continuous and is not broken during the pouring operation, whereas an aluminium-free brass cannot be poured in this way as the oxide skin is not strong enough, and, even with the Durville process, is liable to break up and form small ridges. There is an alternative method, and that is by the addition of phosphorus, the presence of which prevents the formation of a skin of solid oxide. This amount of phosphorus however (0·05), has a considerable effect on other properties of brass, notably in raising there crystallisation temperature after cold working.

Turbulent pouring, apart from its effect on the surface skin of oxide, also results in a considerable amount of splashing, small globules of metal being thrown up by the incoming stream. The volatilisation of the oil base mould coating, where used, also causes much splashing. These splashes solidify on the cold wall of the mould above the surface of the metal, and if the pouring temperature and rate of pouring are low, there is not sufficient heat in the liquid metal as it rises up the mould to remelt them completely. Such defects are readily avoided by pouring at a higher temperature and with sufficient speed, provided the splashes are not badly oxidised, and in ordinary brass practice it is safe to say that the higher the pouring temperature and the more rapid the pouring, the better the surface.

Damp mould gives trouble due to the generation of steam. Apart from this however, if a high melting-point alloy is poured in cast iron moulds under conditions causing local over-heating of the mould surface a new defect is encountered. Gas is given off due to a reaction between the oxidised mould face and the combined carbon in the iron. This gas forces itself into the ingot, forming disastrous surface holes. With aluminium alloys this situation does not arise owing to the lower casting temperature, and with ordinary brasses it is easily avoided by keeping the mould temperature down to something of the order of 100° to 150° C. and avoiding steady impingement of the incoming stream on a particular area of the mould face. With higher melting point alloys the danger of over-heating to an extent sufficient to give this trouble is increased, but when the cause is appreciated it is not difficult to avoid "blowing."

Another type of surface defect may be caused by the mould, due to the tendency of cast iron moulds to crack transversely after repeated use. Such cracks are caused by thermal stresses resulting from the steep temperature gradients in the mould wall immediately after pouring, and it is general practice to reject moulds which are sufficiently badly cracked to affect the surface of the ingot in this way. Both "blowing" and surface cracking of the moulds are avoided by using copper-faced moulds.

Particularly serious in aluminium alloys is the formation of a surface layer or of globules of a low melting point constituent on the surface of the ingot. When the initially formed shell of solid metal shrinks away from the mould wall a small space is left in which the eutectic is liable to run, either filling up the space completely or forming globules at particular points. These eutectics are hard and brittle and affect the rolling properties of the surface layers. An enormous amount has been said about the causes of inverse segregation and of the formation of exudations of this type. The author does not believe gases to be by any means the sole or even the main factor responsible, but the work in progress on this subject at the British Non-Ferrous Metals Research Association is not sufficiently advanced to permit any completely satisfactory explanation nor to suggest immediate remedies for this trouble.

Internal Defects

The most important types of internal defect in ingots are produced by the inclusion of gases either as spherical cavities or as interdendritic voids of irregular shape. The shape of the voids produced by the rejection of dissolved gases during solidification depends largely on the temperature gradients in the casting and the freezing range of the alloy concerned. In a material with a short freezing range, such as commercial aluminium, more or less spherical cavities result which are liable to form blisters in rolled sheet. On the other hand with an alloy like the 95/5 tin-bronze, cavities due to evolved gas form interdendritic fissures which are not very obvious, but form considerable areas of discontinuity and have a markedly adverse effect on mechanical properties. In the case of aluminium alloys the most effective remedy is the use of degassing treatment prior to pouring, and quite a number of such treatments are available. With copper alloys, melting under oxidising conditions has a very considerable effect in preventing gas absorption both by avoiding the presence of excessive reducing gases in the furnace atmosphere and by increasing the oxygen content of the molten metal which has the simultaneous effect of reducing the hydrogen content. It is, however, not possible with many alloys to produce sufficiently strongly oxidising conditions completely to prevent the absorption of reducing gases. Degassing treatment have also been suggested for copper alloys.

Gas cavities in ingots are not always due to the evolution of gas, but may originate in the trapping of gases from the

mould atmosphere carried into the ingot during pouring. Cavities of this type are seriously detrimental in that being near the surface they readily form blisters in rolled strip which have a very thin skin of metal over the surface.

Apart from cavities of this sort however, a stream of metal penetrating well into the solidifying metal already in the mould inevitably injects small bubbles of air or other gases from the mould atmosphere. These small bubbles are very readily entrapped, particularly if the ingot is of thin section.

The wider the section of the ingot, the slower the solidification and the less the danger of entrapped gases. Where thin ingots are necessary, the first and most obvious step for the avoidance of cavities of entrapped gas is to pour the metal at as high a temperature and rapid a speed as other conditions permit. Other factors are important, not the least of which is the position of the mould. In older practice ingots for strip rolling were commonly poured with the mould inclined at an angle against the pouring bench. The use of an inclined mould however, has the effect of increasing the tendency for trapping gases under the upper surface of the ingot. Pouring the ingot in a vertical mould requires the use of a pouring bowl, but this has the added advantage that instead of being poured in a single heavy stream, the incoming metal can be distributed in a number of small streams across the width of the ingot. Bubbles are not carried down so far into the ingot, and have a better chance of escaping. For the complete avoidance of injected gases however, some method of non-turbulent pouring which avoids the carrying of gases into the ingot is desirable.

Contraction on solidification results in piping of the head of the ingot which of course must be fed in some way. This is usually looked after by "following up" with small additions of metal, the use of a hot dozzle as is common in steel practice being very rare in the non-ferrous foundry. The hot dozzle is an ideal method of feeding contraction, but is liable to introduce difficulties, particularly if particles of refractory become detached and trapped in the ingot. In the case of chill-cast ingots of the ordinary type, shrinkage cannot generally be fed completely with the result that the ingots contain internal cavities which are commonly concentrated more or less in the centre of the section where they are not so serious as they are liable to be in sand castings. With long thin ingots such as are widely used in casting copper alloy ingots for strip, central shrinkage unsoundness is almost impossible to avoid. The slower the pouring speed, particularly if a tun-dish is used, the closer the approach to directional solidification. From the practical point of view the best way of reducing internal shrinkage cavities is to cast thicker ingots of a shorter length. If such ingots are properly fed so as to keep the top of the ingot hot, then approximation to directional solidification is more readily secured and internal shrinkage cavities will be correspondingly reduced.

There is a danger with many alloys that fine particles of slag or oxides in suspension in the molten metal will find their way into the ingot. Such particles not only form non-metallic discontinuities having an adverse effect on the strength of the metal, but are likely to result in fine surface blemishes in rolled metal, and where the oxides are very hard, to give trouble in machining operations. A thorough discussion of the subject of deoxidisers would require a great deal of space. Phosphorus is the most commonly employed deoxidant for copper alloys and owes its utility to the fact that it forms fluid deoxidation products of the phosphate type which readily aggregate into particles of sufficient size to rise to the surface of the melt. It is of course quite useless with aluminium, and there is some doubt as to whether phosphorus will deoxide tin oxide once it has been allowed to form in the metal. Where oxidising melting conditions have been used, it is important as far as possible to deoxidise the melt before making additions of elements like tin, the oxides of which once formed are not easy to remove. Correct deoxidation is also very important in the case mentioned earlier of alloys which are liable to gas unsoundness owing to reaction between a readily oxidisable element and dissolved oxygen existing in equilibrium in the melt. Copper and certain nickel alloys are particularly important in this connection, and a wide variety of deoxidising agents including such materials as the alkali and alkaline earth elements have been suggested for this purpose.

Having ensured as far as possible a bath of molten metal which is free from oxides and other non-metallic inclusions, it is important to avoid the introduction of oxides during pouring either by pouring in an inert atmosphere, or as mentioned, by pouring without turbulence so that the skin of oxide on the surface of the metal itself protects against further oxidation.

Mineral Production of Canada in 1938

A preliminary estimate of Canada's mineral production in 1938 indicates a value amounting to \$440,634,000, as compared with the record total of \$457,359,092 achieved in 1937. Many outstanding developments were reported during the year just passed, which offset, to a considerable extent, the decrease of 4% in the aggregate value attributed almost entirely to the decline in base metal prices, and to the falling in sales of some of the more important non-metallic minerals. Gold output reached a new peak of 4,679,685 ozs., nearly 600,000 ozs. greater than in 1937. The productive field was, moreover, widened during the year.

Canada's mining industry is now definitely established on a firm basis, and its success reacts favourably on the whole economic life of the country. During the year copper, lead and zinc were produced in greater quantities than ever before, a fact which is masked to some extent by the decreased prices realised for the output. The discovery of an extensive and new ore body at the Waite-Amulet mine in Quebec added to the economic importance of the property, and during the year a new railway branch-line was completed to serve the important mining belt in the north-western area of the province.

Features at Annual Meeting of Institute of Metals

The thirty-first Annual General Meeting of the Institute of Metals will be held in London on March 8 and 9, and will embody certain new features. In addition to the usual list of papers to be read and discussed—on March 8—there will be two General Discussions extending over the whole of the final day of the Meeting. At the morning session on March 9 the subject of debate will be "The Effect of Work on the Mechanical Properties of Non-Ferrous Metals," and, in the afternoon the discussion topic will be "Industrial Application of Spectrography in the Non-Ferrous Metallurgical Industry."

At the business session with which the Meeting opens on March 8, the second annual award of the Institute of Metals medal will be made, the recipient being Sir Harold Carpenter, F.R.S., a Past-President and Fellow of the Institute. The medal—of pure platinum—is the gift to the Council of the Institute of the Mond Nickel Company Limited, and was designed by Mr. Harold Stabler. The first award of the medal was made last year to Sir William Bragg, O.M., P.R.S.

In the evening of March 8, the Annual Dinner and Dance of the Institute of Metals will be held at Grosvenor House under the Chairmanship of Dr. C. H. Desch, F.R.S., President of the Institute. Invitations to attend the meeting can be obtained from the Secretary, Mr. G. Shaw Scott, 4, Grosvenor Gardens, London, S.W. 1.

Business Notes and News

Iron and Steel Trade

Business in the iron and steel trade is developing a little quicker than at the early part of the year, but manufacturers are still finding the position rather disappointing as a marked forward movement was confidently expected. Confidence of consumers has not yet returned, and in consequence operations are still on a short term basis, despite the stabilisation of prices. It is probable that the price factor is one of the causes, as in view of the fact that the plants in the industry are not working to capacity, supplies are readily obtained, and nothing is to be gained by covering requirements over a long period.

A stimulus has been given by the placing of orders in connection with the A.R.P. shelter scheme. Contracts have been widely distributed. However, the volume of work in the steel trade is only moderate and an expansion in production would occasion no difficulty. Structural steel mills and rail mills are maintaining steady activity, but little demand is being experienced for shipbuilding materials. The demand for pig iron is steady, and production is being absorbed without the accumulation of large stocks, although stocks of hæmatite appear to be accumulating.

Aluminium Works for Cardiff

An aluminium alloy works is to be established at Cardiff by International Alloys, Ltd. The City Council, it is understood, has approved the sale of 20 acres of land for the erection of a factory and gave the company an option over another 40 acres.

British Motor-Cycles Preferred in Holland

A month or two ago certain Dutch dealers in motor-cycles relinquished their agencies for German machines and now it seems likely that, very soon, British motor-cycle makers will have completely recaptured those markets in Holland which they lost two or three years ago, when the subsidised German makers flooded the country with cheap machines.

Already Dutch riders are expressing dissatisfaction with the German types, in which "Ersatz-Material" (substitute material) figures prominently. Artificial rubber, inferior alloys in place of steel and "plastic" replacements for vital metal parts are some of the features which make the reliability and longevity of German mounts compare unfavourably with British products. It is not surprising, therefore, that a number of English makers, such as the Ariel concern, of Birmingham, which formerly shipped huge quantities of motor-cycles to the Netherlands, are steadily re-establishing themselves in this corner of Europe.

Works' Extension of James Booth's

In connection with extensions to their works which are being made by Messrs. James Booth and Co. (1915), Ltd., it is of interest that rolling mill plant contracts have been placed with the Brightside Foundry and Engineering Co., Ltd., and Davy and United Engineering Co., Ltd. The former consists of four cold sheet finishing mill trains, each comprising one centrally located 300 h.p. normal double reduction gear drive, incorporating high-speed flywheels and friction drives to top rolls; one stand of roll housings located on each side of drive, with bottom spindles of universal pattern; one mill train having rolls 28 in. × 8 ft., and three mill trains having rolls 28 in. × 6 ft.

The Davy and United Engineering Co.'s contract consists of three cold sheet finishing mill trains, each comprising one centrally located 200 h.p. normal double reduction gear drive, incorporating high-speed flywheels and friction drives to top rolls; one stand of 24 in. × 4 ft. 6 in. roll housings located on each side of the drive, with bottom mill spindles of universal design.

Joshua Bigwood's and Britannia Lathe and Oil Engine Co.

Messrs. Joshua Bigwood and Son, Ltd., Engineers and Ironfounders of Wolverhampton, manufacturers of special purpose machine tools, announce that they have purchased the goodwill, including all drawings, patterns, jigs, tools, records and work in progress of the general purpose lathes made by the Britannia Lathe and Oil Engine Co. Ltd., of Colchester. These lathes range from 4½ to 9 in. centres and will, in future, be made at Messrs. Bigwood's Wednesfield Road Works in Wolverhampton. A large number of these lathes are at present in course of construction and early deliveries, we understand, can be given.

We are informed that the general design of these lathes is being improved, embodying the latest machine tool practice and special plant and equipment for manufacturing them by modern methods will be installed. Messrs. Bigwoods will also be able to supply spare parts for all previous models of the Britannia Lathe Company's machines and all communications regarding them should be addressed to Messrs. Joshua Bigwood and Son, Ltd., Wednesfield Road, Wolverhampton.

New Coke Ovens for Durham

East Hetton Collieries, Ltd., are to install a new by-product coking plant at Trimdon Grange. The existing waste-heat ovens are to be demolished, and the new plant is to be erected on the same site. The contract for the whole of the work, including the demolition of the present ovens, the installation of the new by-product coking plant, new boiler plant, and all electrical equipment has been placed with Simon-Carves, Ltd., of Cheadle Heath, Stockport. The new ovens are of the Simon-Carves "Underjet" rich gas type, and the installation will be capable of carbonising 400 tons of raw coal a day, with a complete by-product plant, including benzole rectification, and a plant for dealing with crude benzole obtained from other sources.

Shipping and Shipbuilding Problems

Shipping has been seriously affected by the decline in the volume of world trade; idle tonnage being now greater than a year ago. The scarcity of cargoes has involved a severe fall in freight rates. In the present state of world affairs, it is not possible to regard the deterioration of this industry as a matter apart from the strategic position of this country; in addition, it contributes a vital part to the country's balance of trade by means of invisible exports.

Faced with reduced earnings and greatly increased building costs, it is uneconomic for British ship owners to replace their vessels as they wear out. In comparison, there are now being built for competition with British tramps a large number of modern high-speed foreign tramp and cargo liners, especially for Italy, Japan, and Scandinavian countries. Thus the outlook for British shipbuilding is not reassuring. Construction of both large and small vessels on Admiralty account have kept some areas busily employed, but new orders for mercantile vessels have been disappointing, although a contract recently placed by Turkey for eleven vessels is an exception.

The well-equipped and efficiently managed shipbuilding industry is seriously handicapped by unfair and subsidised foreign competition, and in view of its vital importance to the nation it is to be hoped that early steps may be taken to ensure that both shipping and shipbuilding will receive the assistance they are so much in need of to effectively counterbalance the uneconomic competitive advantages of foreign countries.

International Harvester Co. of Great Britain, Ltd., propose to build a factory at Doncaster for the manufacture of commercial lorries and agricultural machinery. The company, it is understood, has purchased a 33-acre site and building will shortly commence. The factory will be built in units in order that production may start as early as possible.

Messrs. Kelvin, Bottomley and Baird, Ltd., are having a new factory built on the Scottish Industrial Estate at Hillington. The factory, which is expected to be occupied in July, will have a floor space of 86,000 sq. ft., and will be the biggest factory on the estate. Messrs. Kelvin, Bottomley, and Baird are makers of navigational and electrical instruments who anticipate a 25% extension in their manufacturing activities.

MARKET PRICES

ALUMINIUM.

98/99% Purity		£94	0	0

ANTIMONY.

English		£71	0	0
Chinese		49	0	0
Crude		36	0	0

BRASS.

Solid Drawn Tubes	lb.	0	0	11¼
Brazed Tubes	,,	0	1	1½
Rods Drawn	,,	0	0	9⅜
Wire	,,	0	0	8½
*Extruded Brass Bars	,,	0	0	4⅞

COPPER.

Standard Cash		£42	17	0
Electrolytic		48	10	0
Best Selected		47	5	0
Tough		48	0	0
Sheets		78	0	0
Wire Bars		48	10	0
Ingot Bars		48	10	0
Solid Drawn Tubes	lb.	0	1	0¼
Brazed Tubes	,,	0	1	0¾

FERRO ALLOYS.

‡Tungsten Metal ° Powder, nominal	lb.	£0	4	9¼
‡Ferro Tungsten ° nominal	,,	0	4	8
Ferro Molybdenum ° ,,		0	4	10
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL: 2–4% Carbon, scale 12/- per unit	ton	34	15	0
NOMINAL: 4–6% Carbon, scale 8/- per unit	,,	24	5	0
NOMINAL: 6–8 Carbon, scale 7/6 per unit	,,	23	15	0
NOMINAL: 8–10% Carbon, scale 7/6 per unit	,,	23	15	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steel-work. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 12/6 per unit	,,	37	0	0
Guar. max. 1% Carbon, scale 13/- per unit	,,	39	0	0
§Guar. max. 0.5% Carbon, scale 13/- per unit	,,	49	0	0
‡Manganese Metal 97–98% Mn	lb.	0	1	3
‡Metallic Chromium	,,	0	2	6
§Ferro-Vanadium 25–50%	,,	0	14	0
§Spiegel, 18–20%	ton	11	0	0
Ferro Silicon— Basis 10%, scale 3/- per unit nominal	ton	10	5	0
20/30% basis 25%, scale 3/6 per unit	,,	12	0	0
45/50% basis 45%, scale 5/- per unit	,,	12	10	0
70/80% basis 75%, scale 7/- per unit	,,	17	0	0
90/95% basis 90%, scale 10/- per unit	,,	30	0	0
§Silico Manganese 65/75% Mn, basis 65% Mn	,,	15	15	0
§Ferro-Carbon Titanium, 15/18% Ti	lb.	0	0	4½
Ferro Phosphorus, 20–25%	ton	22	0	0
§Ferro-Molybdenum, Molyte	lb.	0	4	9
§Calcium Molybdate	,,	0	4	7

FUELS.

Foundry Coke—				
S. Wales	—	2	0	0
Scotland	—	1	10	0
Durham	—	1	14	6
Furnace Coke—				
Scotland	—	1	7	6
S. Wales	—	1	7	6
Durham	—	1	4	2

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)		£66	0	0
*Commercial Ingots		49	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	0	11
*Cored Bars	,,	0	1	1

MANUFACTURED IRON.

Scotland—			
Crown Bars	£12	5	0
N.E. Coast—			
Rivets	—		
Best Bars	12	15	0
Crown Bars	12	5	0
Lancashire—			
Crown Bars	12	5	0
Hoops	13	12	6
Midlands—			
Crown Bars	12	5	0
Marked Bars	15	5	0
Unmarked Bars	—		
Nut and Bolt Bars	11	0	0
Gas Strip	13	12	6
S. Yorks.—			
Best Bars	12	5	0
Hoops	13	12	6

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	£0	0	11
*Cored Bars	,,	0	1	1
†Strip	,,	0	0	11¼
†Sheet to 10 W.G.	,,	0	1	0
†Wire	,,	0	1	1⅜
†Rods	,,	0	1	1¼
†Tubes	,,	0	1	6¾
†Castings	,,	0	1	3

†10% Phos. Cop. £33 above B.S.
†15% Phos. Cop. £38 above B.S.
†Phos. Tin (5%) £32 above English Ingots.

PIG IRON.

Scotland—			
Hæmatite M/Nos.	£6	13	0
Foundry No. 1	6	0	6
,, No. 3	5	18	0
N.E. Coast—			
Hæmatite No. 1	6	0	0
Foundry No. 1	5	2	0
,, No. 3	4	19	0
,, No. 4	4	18	0
Silicon Iron	—		
Forge	4	18	0
Midlands—			
N. Staffs. Forge No. 4	4	18	0
,, Foundry No. 3	5	1	0
Northants—			
Foundry No. 1	5	1	6
Forge No. 4	4	17	6
Foundry No. 3	4	18	6
Derbyshire Forge	4	18	0
,, Foundry No. 1	5	4	0
,, Foundry No. 3	5	1	0
West Coast Hæmatite	6	12	0
East ,, ,,	6	11	0

SWEDISH CHARCOAL IRON AND STEEL.

Export pig-iron, maximum percentage of sulphur 0·015, of phosphorus 0·025.
Per English ton Kr.170
Billets, single welded, over 0·45 Carbon.
Per metric ton Kr.335-385
Per English ton .. £17 11 3/£20 3 9
Wire Rods, over 0·45 Carbon.
Per metric ton Kr.375-405
Per English ton .. £19 12 2/£21 4 9
Rolled Martin Iron, basis price.
Per metric ton Kr.230-250
Per English ton .. £12 1 2/£13 2 2
Rolled charcoal iron, finished bars, basis price.
Per metric ton Kr.360
Per English ton £18 17 6
f.o.b. Gothenburg.

SCRAP METAL.

Copper, Clean	£35	0	0
,, Braziery	33	0	0
,, Wire	—		
Brass	21	10	0
Gun Metal	35	0	0
Zinc	8	10	0
Aluminium Cuttings	59	0	0
Lead	13	10	0
Heavy Steel—			
S. Wales	3	2	0
Scotland	2	19	0
Cleveland	3	0	0
Cast Iron—			
Midlands	2	15	0
S. Wales	3	2	0
Cleveland	3	12	6
Steel Turnings—			
Cleveland	—		
Midlands	2	0	0
Cast Iron Borings—			
Cleveland	—		
Scotland	1	14	0

SPELTER.

G.O.B. Official	—		
Hard	£9	0	0
English	14	12	6
India	13	5	0
Re-melted	10	5	0

STEEL.

Ship, Bridge, and Tank Plates.			
Scotland	£10	10	6
North-East Coast	10	10	6
Midlands	10	10	6
Boiler Plates (Land) Scotland	11	8	0
,, ,, (Marine) ,,	—		
,, ,, (Land), N.E.Coast	11	8	0
,, ,, (Marine) ,,	—		
Angles, Scotland	10	8	0
,, North-East Coast	10	8	0
,, Midlands	10	8	0
Joists	10	8	0
Heavy Rails	9	10	0
Fishplates	13	10	0
Light Rails	9	13	6
Sheffield—			
Siemens Acid Billets	10	10	0
Hard Basic .. £8 10 0 to	10	0	0
Medium Basic, £7 12 6 to	7	17	6
Soft Basic	7	7	6
Hoops	11	15	0
Manchester			
Hoops	12	7	0
Scotland, Sheets 24 B.G.	14	15	0

¶ HIGH-SPEED TOOL STEEL.

Finished Bars 14% Tungsten	lb.	£0	3	0
Finished Bars 18% Tungsten	,,	0	3	10
Extras:				
Round and Squares, ½ in. to ¼ in.	,,	0	0	3
Under ¼ in. to 3/16 in.	,,	0	1	0
Round and Squares, 3 in.	,,	0	0	4
Flats under 1 in. × ⅜ in.	,,	0	0	3
,, ,, ⅜ in. × ⅛ in.	,,	0	1	0

TIN.

Standard Cash	£215	2	6
English	215	5	0
Australian	—		
Eastern	217	17	6
Tin Plates I.C. 20 × 14 box	1	0	3

ZINC.

English Sheets	£28	15	0
Rods	18	0	0
Battery Plates	—		
Boiler Plates	—		

LEAD.

Soft Foreign	£14	5	0
English	16	5	0

* McKechnie Brothers, Ltd., Feb. 11. † C. Clifford & Sons, Ltd., Feb. 11. ‡ Murex Limited, Feb. 11.
Subject to Market fluctuations. Buyers are advised to send inquiries for current prices when about to place order.
§ Prices ex warehouse, Feb. 11. ¶ The prices fluctuate with the price of Tungsten

METALLURGIA. ## *Contents.* For FEBRUARY, 1939.

ADVERTISERS' ANALYSIS

Acids
Imperial Chemical Industries, Ltd., Imperial Chemical House, London, S.W. 1.

Alloys
J. H. Clifton, London.
Electric Furnace Products Co., Ltd., Norway.

Aluminium and its Alloys
Aluminium Union, Ltd., The Adelphi, Strand, London, W.C. 2.
High Duty Alloys, Ltd., Trading Estate, Slough.
Wm. Mills, Ltd., Birmingham.
Northern Aluminium Co., Ltd., Bush House, London, W.C. 2.
Priestman, T. J., Ltd., Birmingham.
Perry Barr Metal Co., Ltd., Birmingham.

Anti-Friction Metals
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Brass and Bronze
Billington & Newton Ltd., Longport.
Clifford, Chas. and Son, Ltd., Birmingham.
Emery Bros., Ltd., Aston, Birmingham.
I.C.I. Metals Ltd., Birmingham.
John Holroyd, Ltd., Rochdale.
Manganese Bronze & Brass Co., Ltd., Handford Works, Ipswich.
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Casehardening Compounds
Amalgams Co., Ltd., Attercliffe Rd., Sheffield.
G.W.B. Electric Furnaces, Ltd., Belgrave House, Belgrave St., W.C. 1.
I.C.I. Cassel Cyanide.
Kasenit Ltd., Holyrood St., Bermondsey St., London, S.E. 1.

Castings (Iron)
Rudge Littley Ltd., West Bromwich.
Wallwork, H., and Co., Ltd., Roger St., Manchester.

Castings (Non-ferrous)
Magnesium Castings and Products, Ltd., Slough.
Manganese Bronze & Brass Co. Ltd., Handford Works, Ipswich.
William Mills, Limited, Grove St., Birmingham.
Mond Nickel Co., Ltd., Thames House, Millbank, London, S.W. 1.
Northern Aluminium Co. Ltd., Bush House, Aldwych, London, W.C. 2.
Sterling Metals Ltd., Coventry.

CO_2 Recorders
Honeywell Brown, Ltd., 70, St. Thomas St., London.

Coke-Oven Plant
Gibbon Bros., Ltd., Albert Rd., Middlesbrough.

Crucibles
Morgan Crucible Co. Ltd., Battersea Church Rd., London, S. W. 11.

Diecastings
Diecastings, Ltd., Moseley Rd., Birmingham 12.

Electrodes
British Acheson Electrodes, Ltd., Sheffield.

Extruded Rods and Sections
McKechnie Bros., Ltd., Rotton Park St., Birmingham.
Northern Aluminium Co., Ltd., London.

Fluxes
Foundry Services Ltd., 285, Long Acre, Nechells, Birmingham.
Imperial Chemical Industries Ltd., Dept. C. 6, Imperial Chemical House, London, S.W. 1.

Forgings
Northern Aluminium Co., Ltd., London.

Foundry Preparations
Foundry Services Ltd., 285, Long Acre, Nechells, Birmingham.
Imperial Chemical Industries Ltd., Dept. C.6, Imperial Chemical House, London, S.W. 1.
J. W. Jackman & Co., Ltd., Vulcan Works, Blackfriars Rd., Manchester.
Thos. Wilkinson & Co., Ltd., Middlesbrough.

Furnaces (Electric)
Birmingham Electric Furnaces, Ltd., Erdington, Birmingham.
Demag Electrostahl, Germany.
Electric Furnace Co., Ltd., 17, Victoria St., London, S.W. 1.
General Electric Co., Ltd., Magnet House, Kingsway, W.C. 2.
G. W. B. Electric Furnaces, Ltd., Belgrave House, Belgrave St., London, W.C. 1.
Metalectric Furnaces Ltd., Cornwall Rd., Smethwick, Birmingham.
Morgan Crucible Co. Ltd., Battersea Church Road, London, S.W. 11.
Siemens Schuckert, Ltd., New Bridge Street, London.
Wild-Barfield Electric Furnaces, Ltd., Elecfurn Works, North Rd., London, N. 7.

Furnaces (Fuel)
Brayshaw Furnaces Ltd., Manchester.
British Furnaces Ltd., Chesterfield.
Burdon Furnace Co., Hillington, Glasgow.
Cassel Cyanide Co., Ltd., Room 170F2, Imperial Chemical House, London, S.W. 1.
Dowson and Mason Gas Plant Co., Ltd., Levenshulme, Manchester.
Gibbons Brothers, Ltd., Dudley, Worcestershire.
Incandescent Heat Co., Cornwall Rd., Smethwick, Birmingham.
Kasenit Ltd., Holyrood St., Bermondsey St., London, S.E. 1.
King, Taudevin & Gregson, Ltd., Sheffield.
Ofag Ofenbau, Düsseldorf, Germany.
Priest Furnaces Ltd., Albert Road, Middlesbrough.
Wellman Smith Owen Engineering Corporation Ltd., Victoria Station House, London.

Fused Blocks
Imperial Chemical Industries Ltd., Dept. C.6, Imperial Chemical House, London, S.W. 1.

Gas
British Commercial Gas Association, Gas Industry House, 1, Grosvenor Place, London, S.W. 1.

Gears
Wallwork, Henry, and Co., Ltd., Red Bank, Manchester.
Shorter Process Co., Ltd., Savile St. East, Sheffield.

Gun Metal Ingots and Rods
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Hardening Metals
Shorter Process Co. Ltd., Savile St. East, Sheffield.
I.C.I. Cassel Cyanide.

Ingots (Non-Ferrous)
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Ironfounders.
Joshua Bigwood & Son, Ltd., Wolverhampton.

Machinery
Joshua Bigwood & Son, Ltd., Wolverhampton.

Machine Tools
Sanderson Brothers and Newbould Ltd., Sheffield.

Magnesium Alloys
F. A. Hughes Ltd., London.
Magnesium Castings, Ltd., Slough.
Sterling Metals, Ltd., Coventry.

Magnetic Separators, Clutches, Chucks, and Lifting Magnets
Electromagnets, Ltd., 48, High St., Erdington, Birmingham.
Metallisation Ltd., Dudley.

Metal Spraying

Motors (Electric)
Metropolitan-Vickers, Ltd., Trafford Park, Manchester.

Naval Brass Ingots
McKechnie Bros. Ltd., Rotton Park St., Birmingham.

Non-Ferrous Metals
Birmetals, Ltd.
Reynolds Tube Co., Tyseley, Birmingham.
I.C.I. Metals Ltd., Kynoch Works, Witton, Birmingham, 6.
McKechnie Bros. Ltd., Rotton Park St., Birmingham.
Perry Barr Metal Co., Ltd., Birmingham.

Oil Engines
Mirrlees Bickerton & Day, Ltd., Stockport.

Pig Iron
Barrow Hæmatite Steel Co., Ltd., Barrow-in-Furness.
Bradley & Foster, Ltd., Darlaston.

Presses
Eumuco Ltd., Beverley Works, Willow Ave., Barnes, London, S.W. 13.
Schloemann, A.-G., Düsseldorf, Germany.

Protection of Metal Parts for Use at High Temperatures
Calorizing Corporation of Great Britain, Ltd., 32, Farringdon St., London, E.C. 4.

Pulverised Fuel Equipment
Alfred Herbert Ltd., Coventry.

Pulverised Fuel Manufacturers
Standard Pulverised Fuel Co., Ltd., 4-5, Norfolk St,, Strand, London, W.C,2.

Pyrometers
Cambridge Instrument Co., Ltd., London.
Electroflo Meters Ltd., Abbey Rd., Park Royal, London, N.W. 1.
Ether Ltd., Tyburn Rd., Birmingham.
Honeywell Brown, Ltd., 70, St. Thomas St., London.
Integra Co., Ltd., 183, Broad St., Birmingham, 15.
Metalectric Furnaces Ltd., Cornwall Rd., Smethwick, Birmingham.

Recording Instruments
Cambridge Instrument Co., Ltd., London.
Dine Engineering Co., 60, Mount St., Nechells, Birmingham.
Electroflo-Meters Co., Ltd., Abbey Rd., Park Royal, London, N.W. 10.
Ether, Ltd., Tyburn Rd., Birmingham.
George Kent Ltd., Luton, Beds.
Integra Co., Ltd., 183, Broad St., Birmingham, 15.
Metalectric Furnaces Ltd., Cornwall Rd., Smethwick, Birmingham.

Refractories
Carborundum Co., Ltd., Trafford Park, Manchester.
J. and J. Dyson, Ltd., Stannington, Sheffield.
Kingscliffe Insulating Products, Ltd., Sheffield.
Thos. Marshall and Co., Loxley, near Sheffield.
Morgan Crucible Co., Ltd., Battersea Church Rd., London, S.W. 11.
John G. Stein & Co., Bonnybridge, Scotland.

Regulators
Honeywell Brown Ltd., 70, St. Thomas St., London.

Roll Grinding Machines
Craven Bros. Ltd., Reddish, Stockport.

Roll Manufacturers
Tennent Ltd., Whifflet Foundry, Coatbridge, Scotland.

Rolling Mills
Demag, A.-G., Germany.
Ehrhardt and Sehmer, Saarbrücken.
Fried. Krupp Grusonwerk A.-G. Magdeburg, Germany. Sole Agents in Great Britain: J. Rolland and Co., 2, Victoria St., London, S.W. 1.
Lamberton and Co., Coatbridge.
Maschinenfabric Froriep, Rheydt, Germany.
Rheinische Walzmachinenfabrik, Germany.
Robertson, W. H. A., and Co., Ltd., Bedford.
August Schmitz, A.-G., Germany.
Karl., Fr. Ungerer., Germany.

Silver Solder
Chas. Harrold & Co. Ltd., 283, St. Paul's Square, Birmingham.

Steels
Barrow Hæmatite Steel Co., Ltd., Barrow-in-Furness.
Edgar Allen & Co., Ltd., Imperial Steel Works, Sheffield.
L. Cameron & Sons, Ltd., Sheffield.
Daniel Doncaster & Sons, Ltd., Sheffield.
Darwins, Ltd., Sheffield.
Dunford & Elliott, Ltd., Sheffield.
Thos. Firth & John Brown, Ltd., Sheffield.
English Steel Corporation Ltd., Sheffield.
Sanderson Bros. and Newbould, Ltd., Sheffield.
United Steel Companies, Ltd., Sheffield.

Steel Sections
Barrow Hæmatite Steel Co., Ltd., Barrow-in-Furness.

Steel Tubes and Sections
Reynolds Tube Co., Tyseley, Birmingham.

Steelworks Plant
Wellman Smith Owen Engineering Corporation, Ltd., Victoria Station House, London, S.W. 1.

Temperature Controllers
Cambridge Instrument Co., Ltd., London.
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Ether, Ltd., Tyburn Rd., Birmingham.
Honeywell Brown, Ltd., 70, St. Thomas St., London, S.E. 1.
Integra Co., Ltd., 183, Broad St., Birmingham, 15.
George Kent, Ltd., Luton.

Testing Machines
Howden, T. C., and Co., 517, Fleet Street, Birmingham.

Thermostatic Controls
Honeywell Brown Ltd., 70, St. Thomas St., London.

Tube Drawing Plant
Sundwiger Eisenhütte, Sundwig, Germany.

Turbines
Richardson, Westgarth Ltd., West Hartlepool.

Vitreosil Combustion Tube
Thermal Syndicate, Ltd., Wallsend-on-Tyne.

X-Ray Apparatus
Victor X-Ray Corporation Ltd., London and Chicago.

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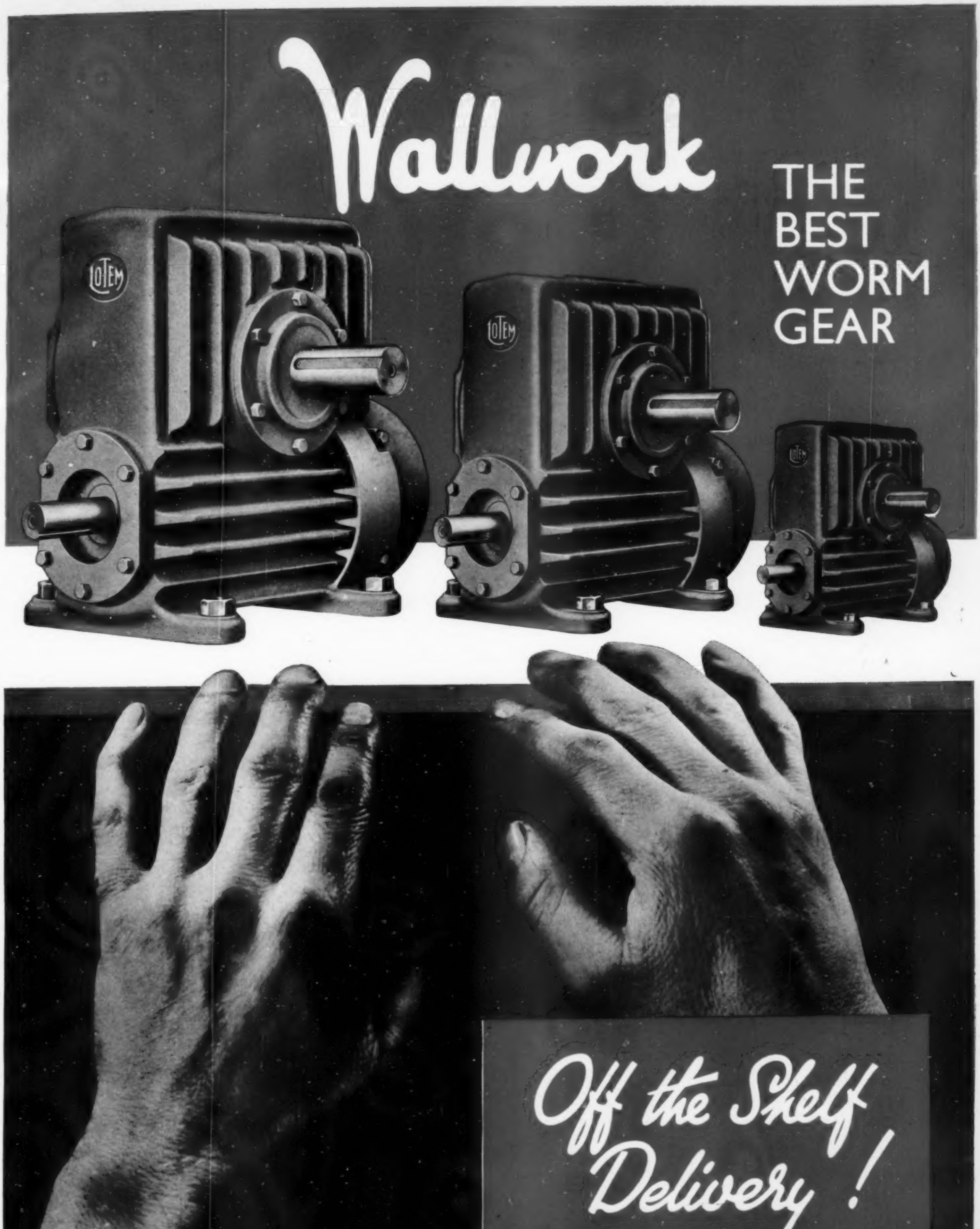

HENRY WALLWORK & CO., LTD., MANCHESTER. Telephone : 1801 (3 lines). Telegrams : " Foundry," Manchester.